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VOLUME 35 NOVEMBER, 1961 NUMBER 6

MORPHOLOGY OF THE BLASTOID *GLOBOBLASTUS NORWOODI*

HAROLD H. BEAVER

Humble Oil & Refining Company, Houston, Texas

ABSTRACT—Thin-section examination of well-preserved specimens of the blastoid *Globoblastus norwoodi* from the Mississippian Burlington limestone of Iowa and Missouri has provided considerable new morphologic information. The anal deltoid, previously known to consist of an epideltoid and hypodeltoid, possesses two additional plates, the right and left cryptodeltoids. The number of hydrospire pores is not proportional to the number of side plates and brachioles as interpreted by early workers. The formation of the hydrospires from a single external spiracle at the calyx summit to their final disappearance at the aboral end of the ambulacrum is shown by a series of drawings based on detailed thin-section analysis of selected specimens.

INTRODUCTION AND ACKNOWLEDGMENTS

FEW studies during the past 60 years have been concerned with the detailed morphology of blastoids. Cline (1936, 1937) redescribed the genera *Schizoblastus* and *Cryptoblastus* in some detail, and Cline & Heuer (1950) reviewed similarly the *Codaster alternatus-Codaster pyramidatus* group. Wanner (1924, 1931, 1940, 1951) also contributed much to knowledge of blastoid morphology in his several papers on the Permian blastoids of Timor. All of these reports, however, have been concerned with characteristics visible on the exterior of blastoids, and little attention has been given to such internal features determinable in sectioned specimens as the development of the hydrospires, the arrangement of the oral ring canal, and the detailed nature of plate relationships.

Structures occurring on the interior of calyces have long been regarded by a few workers as of potential importance in understanding and correctly classifying genera and species of the blastoids. Wachsmuth & Springer (1879, p. 231, footnote) state "that one of us who devoted much time to the study of the blastoids, made a large number of sections of the hydrospires, in different genera, and finds that they form excellent distinctions." Investigations of the interior of blastoid calyces reviewed here and in other reports now in preparation confirm the tentative conclusions of the early workers as to significance of these features. It is evident, therefore, that all morphologic structures—those readily observed on the exterior and those seen only by sectioning—are important in understanding the structural elements of blastoids and in classifying these fossils.

This study is concerned with a detailed description of features observable in the interior of *Globoblastus norwoodi*, the type species of the genus. This species, which occurs abundantly in the Mississippian Burlington limestone, was selected because of its availability and suitability for investigation. Etheridge & Carpenter (1886, p. 286) indi-

cated that "this is a very remarkable species, and will well repay close and attentive study. The deep columnar cavity is a very striking and characteristic feature. . . . A still more noticeable character in many individuals is the extension of all the spiracles, except the anal one, into erect tubular openings."

Approximately 250 specimens, most of them well preserved in a permineralized condition, were used in this investigation. Many of the specimens were collected in the vicinity of Springfield, Missouri, particularly at the Ashgrove quarries. In addition, L. M. Cline made available for sectioning a sizable collection of specimens that were especially suited for morphologic study because of the excellent preservation of the hydrospires in clear crystalline calcite. Some duplicate material at the University of Iowa from the Springer echinoderm collection also was used.

Sections were cut transverse to the summit-basal cavity axis except where particular curving structures could best be studied by longitudinal or oblique cuts. The development of the hydrospires, for example, can be determined most accurately by sections perpendicular to the curving axes of the ambulacra. Likewise the subdivision of the spiracles is seen most clearly in summit thin sections slightly oblique to the longitudinal axis of the calyx. The oral ring canal, because of its convex shape, is studied best in sections thicker than those normally used in paleontologic work.

Thin sections were projected through a 35 mm. slide projector, and line drawings were made directly on the projected image. Detailed relationships were checked by a microscopic examination of the sections. Although thin sections were used exclusively, subsequent investigation indicated that acetate peels may be substituted, particularly where a series of closely spaced serial sections are desired.

My gratitude is extended to L. M. Cline, University of Wisconsin, under whose guidance this work was carried on. His constructive criticism and the use of his extensive blastoid collection are appreciated. R. M. Jeffords, Humble Division, Humble Oil & Refining Company, advised on revision of the manuscript, and T. H. Miller of the same company assisted in the preparation of the illustrations.

SYSTEMATIC DESCRIPTION

Class BLASTOIDEA

Order EUBLASTOIDEA

Genus GLOBOBLASTUS Hambach

Globoblastus norwoodi (Owen & Shumard)

Pl. 129, figs. 1–16; Pl. 130, figs. 1–17

Pentremites norwoodi OWEN & SHUMARD, 1850, p. 64, pl. 7, figs. 13a–c; OWEN, 1852, p. 591, pl. 5A, figs. 13a–c; WHITE, 1863, p. 483.

Elaeacrinus norwoodi SHUMARD, 1863, p. 112.

Granatocrinus norwoodi SHUMARD, 1865, p. 375; MEEK & WORTHEN, 1869, p. 84; MEEK & WORTHEN, 1873, p. 465, pl. 9, figs. 2a–c; WACHSMUTH & SPRINGER, 1881, pl. 19, fig. 6; ETHERIDGE & CARPENTER, 1882, p. 239; ETHERIDGE & CARPENTER, 1886, p. 245–248, pl. 2, figs. 34–36, pl. 3, fig. 16, pl. 6, figs. 19,20, pl. 7, figs. 1–13, pl. 10, fig. 11, pl. 11, fig. 14, pl. 17, fig. 8.

Orbitremites norwoodi BATHER, 1900, p. 90, fig. 12; CLINE, 1944, p. 137, pl. 51, figs. 37–41.

Globoblastus norwoodi HAMBACH, 1903, p. 46; FAY, 1960, p. 292–299, pls. 1–4.

EXPLANATION OF PLATE 129

FIGS. *1–16*—*Globoblastus norwoodi* (Owen & Shumard). *1,4,6,12,14,16,* Ambulacral and interambulacral views. *2,3,5,7,13,15,* Oral views; *5,15* are internal molds; *5* shows a portion of the oral ring canal; summit plates are intact in *7*. *8,9,* Views showing the deep basal cavity. *10,11,* Anal views; *10* shows right and left cryptodeltoids with the hypodeltoid removed; *11* shows the hypodeltoid resting on the cryptodeltoids in normal position. The limbs of the radials between the left posterior and right posterior ambulacra have been removed.

All figures are ×2 except *7* and *8* which are ×4. *1–5,7–9,15,16* are from the Burlington limestone at Burlington, Iowa; *6,10,11,13,14* are of specimens from the upper Burlington limestone at Ashgrove quarry, Springfield, Missouri; and *12* is from the upper Burlington limestone at Bolivia, Missouri.

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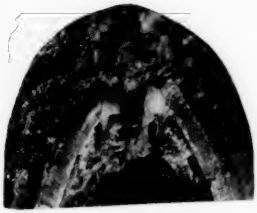
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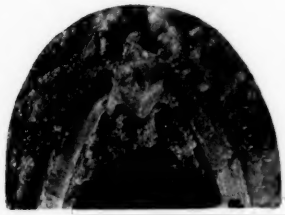
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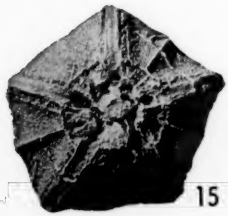
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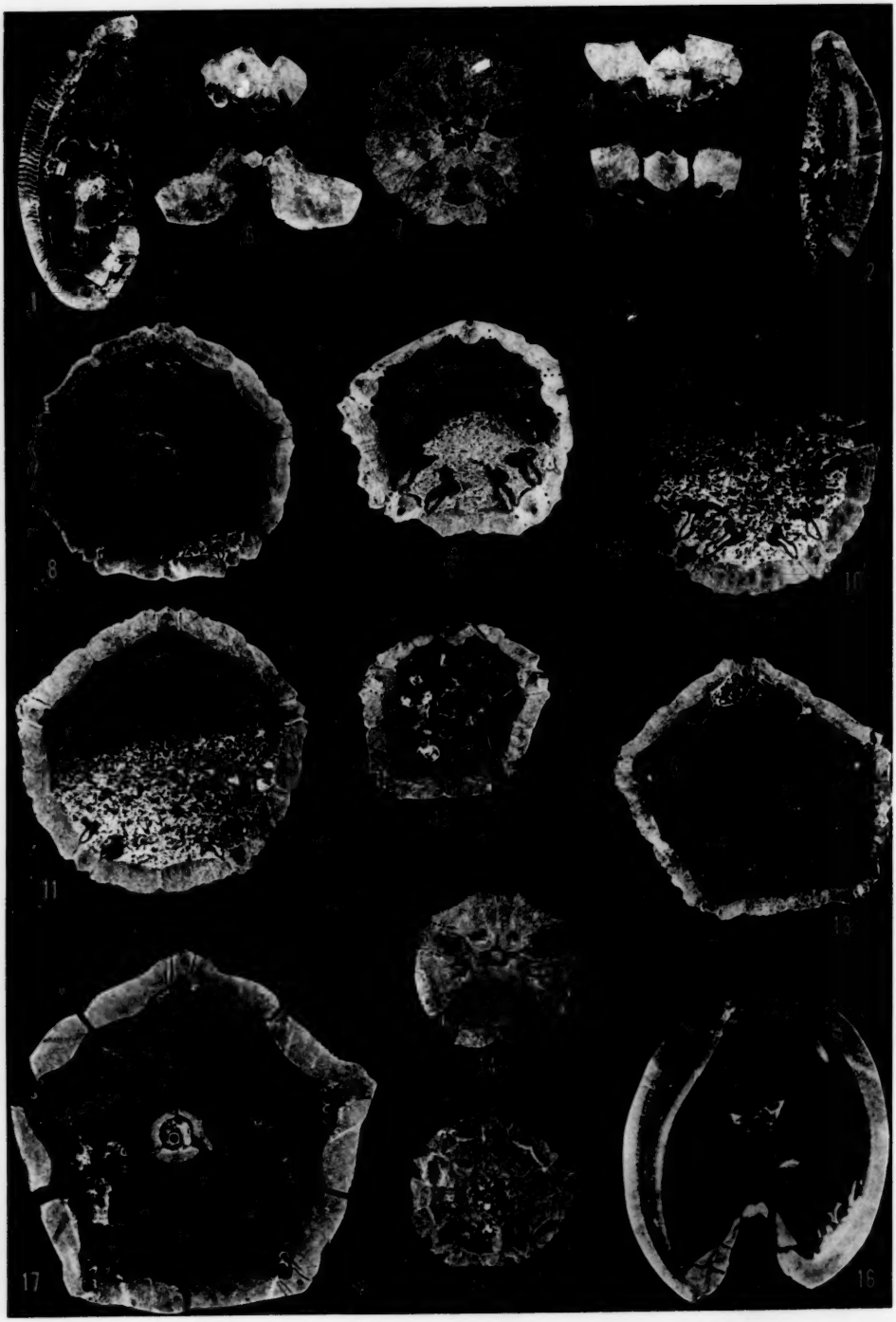


Calyx depressed globose to elongate-ovate; basals small, generally hidden in basal cavity; radials long, overlap deltoids, nearly the height of the calyx, and always turned in to form part of the basal cavity; deltoids small, pierced by five spiracles of which the anal spiracle is largest and is confluent with the anal opening. Ambulacra long, parallel sided; lancets subhexagonal in section, pierced by internal longitudinal canal; side plates small, completely conceal lancets except adorally where median groove is exposed; outer side plates very small; two hydrospires on each side of ambulacrum.

Discussion.—Fay (1960) has removed this species from *Orbitremites* and assigned it to the genus *Globoblastus* because the type species of *Orbitremites*, *O. derbiensis*, differs notably in having long deltoids and in having one hydrospire instead of two on each side of the ambulacra. *Globoblastus norwoodi* also differs from *O. derbiensis* in that the radials overlap the deltoids.

A very large number of specimens were identified as *Globoblastus norwoodi* on the basis of the spiracles piercing the deltoids, the basal cavity, two pairs of hydrospires beneath each ambulacrum, and general shape. Only one specimen representing a markedly different variety was noted. This specimen differs from the typical form of the species in the structure of the lancets, in the shape of the hydrospires and their relation to the radials, in the slightly different ornamental ridges on the exterior of the calyx, and in the elevation of the radial lips which receive the ambulacra. The most obvious difference is the marked concavity of the inner surface of the lancet plates; this characteristic is just the reverse of that of the typical lancets of *G. norwoodi*.

Occurrence.—Upper and lower Burlington limestone, Osagian, Mississippian (Keyes & Rowley, 1897; Rowley, 1900; Van Tuyl, 1925; Moore, 1928).

MORPHOLOGY

Calyx.—The calyx consists of three basals, five radials, five deltoids, ambulacra, hydrospires, and summit plates. The calyx is elongate, globose, subglobose, or elliptical. In some specimens the height exceeds the diameter by several millimeters; in others, the diameter exceeds the height. Commonly, however, the height and diameter are nearly equal. Wachsmuth (1884) suggested that younger stages are elongate-ovate, that medium-sized specimens are subglobose to globose, and that large specimens are depressed globose. The large collection avail-

EXPLANATION OF PLATE 130

FIGS. *1–17*—*Globoblastus norwoodi* (Owen & Shumard). *1,2*, Longitudinal sections of the calyx showing the hydrospire pores which pierce the radials. *1* is of a broken portion of the basals; in *2* the hydrospire pores do not penetrate the deltoid; *3–6*, Transverse sections of the ambulacra. *3*, Development of the hydrospire folds in the lower part of the deltoids; *4*, passageways of the oral ring canal are shown in the center of the lancet, and divided spiracles are beginning to divide into the hydrospire folds; *5*, further development of the hydrospire folds in the deltoids; and *6*, the hydrospires near the aboral end of the ambulacrum; *7,14,15*, Transverse sections of the summit showing the divided spiracles and the anal opening; *8–13,17*, Transverse sections of the calyx. *9,10,12*, Sections just below the radio-deltoid suture; *8,11,13*, sections near the middle of the calyx; *17* illustrates the single specimen that differs structurally from normal specimens. Note the marked concavity of lancet plate and the much greater projection of the radial lips. The section was cut about $\frac{1}{4}$ the height of the calyx above the base. The uppermost portion of the inverted basals can be seen in the center of the section. *16*, Longitudinal section of the calyx showing the basals and one of the hydrospires.

All figures are ×3 except *3–6* which are ×6. *1–7,9,12,13*, and *15–17* are from the upper Burlington limestone at Ashgrove quarry, Springfield, Missouri; and *8,10,11,14* represent specimens collected from the Burlington limestone at Burlington, Iowa.

able for this study does not support such a conclusion. Although some of the small specimens are elongate oval, others are decidedly depressed globose. Some of the very largest specimens, moreover, are distinctly elongate and not at all depressed. Variation in the shape of the calyx is so marked that this feature warrants little consideration as a distinctive specific characteristic.

Basals.—The basals are confined to the basal cavity; the azygous basal is quadrate, the other two are pentagonal. The basal cavity is pentagonal and cone-shaped. The walls of the basals are thinner than those of the radials, so that the basals often are broken or squeezed out of position. At the apex of the basal cavity the diameter is just great enough for the column to pass through, and the basals surround the uppermost columnal. Ornamentation has not been observed on the basals.

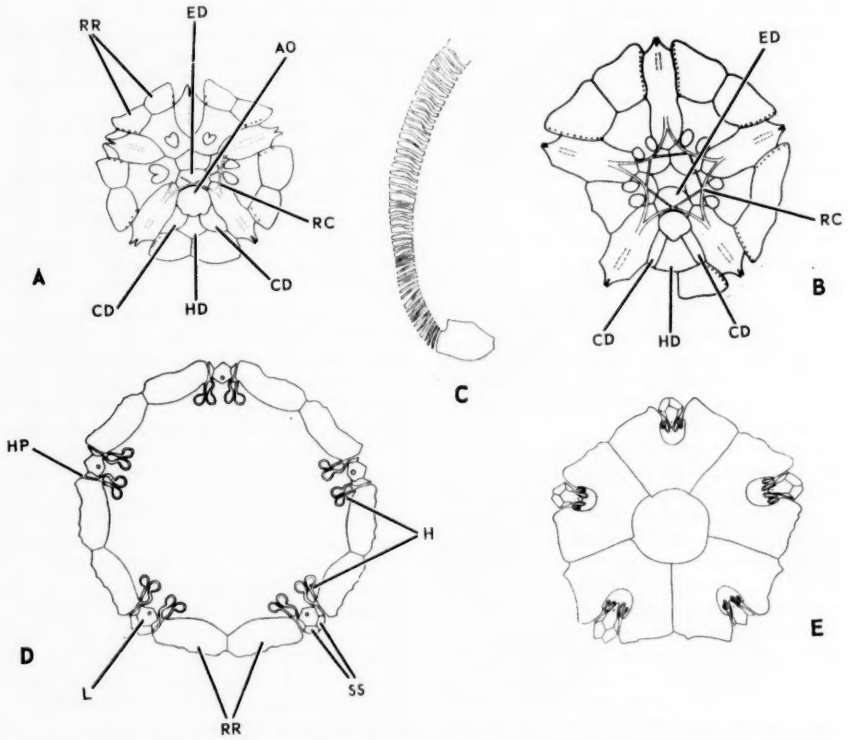
Column.—Little is known concerning the column of *Globoblastus*. Etheridge & Carpenter (1886) describe the column as consisting of "small, thin, discoidal joints, which have no special distinctive marks." The uppermost columnal is radially marked, however, and others probably are marked similarly. The lower surface of the upper columnal bears radial ridges and grooves and, by analogy with other blastoid columnals, these were matched by a corresponding set on the top of the subjacent columnal. These ridges and grooves served in the articulation of the columnals in the column. Each columnal is perforated by a longitudinal opening (circular hole in transverse view) that generally is inferred to have contained nerves extending through the column to the calyx.

Radials.—The five radials alternate and are in contact with the basals within the basal cavity. The contact between the basals and the radials is at a point approximately one-third the height of the basal cavity above the aboral portion of the cavity. Because the ambulacra extend the length of the calyx in this genus, the radials are divided into two almost equal sections. The two limbs are united only within the basal cavity (Text-fig. 1E). Transverse sections through the calyx tend to be pentagonal in many specimens because of the elevation of the ambulacra; circular sections occur where the elevation is less. The angularity of the section also is determined largely by the position of the section. Thus, a section cut a short distance below the radio-deltoid suture has nearly a circular section, whereas a much lower section has a pentagonal outline.

The external surfaces of the radials are marked by longitudinal ridges or by a series of nodes which give a granular appearance. Whether marked by distinct ridges or by rows of nodes, however, the general design is the same. Major rows or ridges begin nearest the deltoids at the interradial sutures and are continued obliquely from the latter suture aborally. At a point which may be near the center of the calyx or slightly higher, they turn and migrate obliquely back towards the interradial suture. Normally they do not quite reach the interradial suture and end at the radio-basal suture within the basal cavity. Each plate generally has two such rows or ridges.

Deltoids and spiracles.—In this species the deltoids are very small and occupy only a small portion of the calyx. The deltoids are more variable in shape than are the radials. The extremes in shape are from triangular to decidedly arrowheadlike, and numerous gradations between these two basic shapes were noted. The spiracles pierce the deltoids and externally consist of five openings. In specimens having distinctly triangular deltoids, the spiracles open toward the opposite ambulacrum. In the arrowhead-shaped deltoids, the spiracles open upwards. Often a half-moon-shaped hood surrounds the aboral portion of the spiracles. The only ornamentation on the deltoids is the crenulated front and side edges which blend with the crenulations of the median longitudinal groove of the lancet and with some irregular depressions on the aboral portion of the deltoids. By analogy with other blastoids such as *Pentremites*, the crenulations evidently played a part in the articulation of the ambulacral covering plates with the food grooves of the lancet and deltoid.

The anal deltoid.—The anal deltoid is made up of four parts bordering the anal opening. The plate nearest the peristome is the *epideltoid* (Pl. 129, figs. 2,3,7,13; Text-figs. 1A,1B). It was originally described by Wanner (1924) in the Permian schizoblas-



TEXT-FIG. *1*—Detailed drawings of plate arrangement in *Globoblastus norwoodi* prepared by sketching relationships observed in thin sections, ×3. (RR = radials; SS = side plates; L = lancet; H = hydrospires; HD = hypodeltoid; Ed = epideltoid; CD = cryptodeltoids; AO = anal opening; RC = oral ring canal.)

A. Section cut almost transverse to the summit showing the division of the spiracles. A portion of the oral ring canal (RC) is shown.
B. Section transverse to the summit. The complete oral ring canal (RC) is shown.
C. Longitudinal section through the hydrospire pores; some pores split, whereas others coalesce.
D. A typical transverse section through the middle of the calyx.
E. Transverse section of the calyx at the lowermost ends of the ambulacra. Note that the ambulacra are embedded in the radials.

toids of Timor and was later observed in the Mississippian schizoblastoids of North America by Cline (1936). Internally, the epideltoid is separated from the remainder of the anal deltoid by a gap where the adjacent lancet plates border the anal opening.

The aboral portion of the anal deltoid is composed of three plates. The hidden, underlying, supporting pieces are here named the right and left *cryptodeltoids* (Text-figs. 1A,1B). Laterally, they are in contact with the adjoining lancets; adorally they border the anal opening. In shape, they are slightly curved and triangular. The *hypodeltoid* (Wanner, 1924) lies aboral to the anal opening and rests upon the right and left cryptodeltoids (Text-figs. 1A,1B). The hypodeltoid is the only aboral portion of the anal deltoid ordinarily observable in external views of unweathered specimens. Both the cryptodeltoids and the hypodeltoid can be observed, however, by removal of the over-

lapping radials, Externally, the hypodeltoid projects out over the anal opening like a hood. Completing the gap between the hood-like hypodeltoid and the epideltoid are two small plates, one on each side, which rest both on the adjoining lancet and on the cryptodeltoid. One of the two small plates is shown in Plate 129, figure 13 (the other is missing); it occupies the position of the adoralmost side plate. The inside edges of the epideltoid are crenulated in the same pattern as the outside edges of the deltoids, lancets, and side plates. These crenulations apparently served the same function as the crenulations of the ambulacra—that of articulation between the summit covering plates and the surfaces of the spiracles and the anal opening. This function is evident in the genus *Pentremites*.

Because the anal spiracle is confluent with the anal opening in *Globoblastus*, differentiation between the two is difficult. In well-preserved specimens, the path of each divided spiracle can be seen on either side of the anal opening; the two paths are well shown in Text-figure 1A, and each opens externally into the general anal opening.

Development of the hydrospires in the deltoids.—The single external spiracle opening divides initially into two canals (Pl. 129, fig. 15). Each of the canals leads into a hydrospire system developed beneath the nearest sides of adjacent ambulacra. A section transverse to the summit and cut at a slightly oblique angle shows the division (Text-fig. 1A). The development of two canals, one on either side of a lancet, into the hydrospires within adjacent deltoids is shown in Text-figures 2A–2E and on Plate 130, figures 3–5. Each of the canals subdivides into two hydrospire folds by infolding of the deltoid material (Text-figs. 2B–2E). At this point, with the hydrospires nearly completely formed, transition from deltoid to radial material occurs.

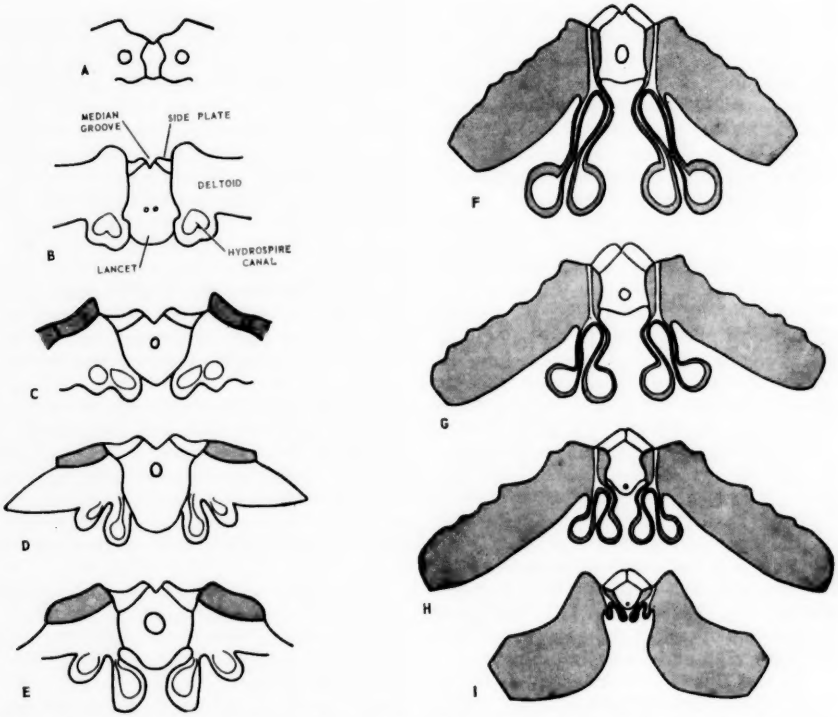
The hydrospires of the radials.—The hydrospires are generally regarded to begin immediately below the deltoids even though they are almost completely formed in the lower portions of the deltoids. In fact, the hydrospires have their greatest size just below the deltoids, and they decrease in size aborally (Pl. 130, fig. 6). Hydrospire size and calyx size do not correspond (Pl. 130, figs. 9,10,12; Text-fig. 2F).

The hydrospires have two constant and unchanging characteristics: first, the two hydrospire tubes on each side of an ambulacrum (a total of four under the ambulacrum), and second, the bending of the innermost half of each pair of hydrospires toward each other immediately under the lancet and then back together where the tubes themselves are located (Text-fig. 1D).

Hambach (1903) suggested this general area for some of his interpreted internal, longitudinally arranged organs. The sections shown in this report do not show such organs, although the gaps between the hydrospire folds are always present in the upper part of the body cavity beneath the deltoids. Aborally, the gap between the walls of adjacent hydrospires tends progressively to decrease so that the gap is just barely discernible near the lower end. The bend of the hydrospire folds is greater in some specimens than in others. If these hydrospire folds expanded and contracted as some have believed (Wachsmuth & Springer, 1879), the general shape at various levels would not be as constant as is observed. It is more likely, therefore, that the hydrospires were relatively nonflexible, finely membranous, and calcareous. Whether their walls or tubes were permeable in life is not determinable from the available material.

Hydrospire pores.—The hydrospire pores are the passageways connecting the hydrospires with the outside. These canals completely pierce the radials but do not extend through the deltoids (Text-figs. 2D–2I; Pl. 130, fig. 2). Externally the passageways open as pores at the outer junction between the side plates and the radials. The pores are larger and are spaced farther apart near the summit than they are aborally (Pl. 130, fig. 1; Text-fig. 1C). Approximately twice as many openings occur aborally as near the summit. Because the number of hydrospire pores increases aborally but the width of the side plates and outer sides plates is constant throughout the length of the ambulacra, no definite relationship exists.

Lancets.—The lancets are the main supporting pieces of the ambulacra and radiate aborally in five directions from the summit. Because of the length of the ambulacra, they extend the length of the calyx. Two struc-



TEXT-FIG. 2—A series of drawings of thin sections of *Globoblastus norwoodi* cut perpendicular to an ambulacrum showing the development of the hydrospires; the deltoids are unshaded, the radials are stippled. ×7.

A. Section at the adoral end of the ambulacrum showing one of the divided hydrospire canals on each side of the lancet.

B. Section slightly below *A*. The division of the hydrospire canals shown in *A* takes place by infolding of deltoidal material. The longitudinal canal of the lancet has divided. Between *A* and *B* the two canals separate farther and farther and leave the lancet on their respective sides to form the oral ring canal.

C. Section just below the radio-deltoid suture. The radials (stippled areas) rest on the deltoids. The division of the hydrospire canals within the deltoids has been completed.

D. Section below *C*; the hydrospire folds are taking form.

E. Section below *D*; hydrospire development is still in deltoid material.

F. Section a short distance below the radio-deltoid suture; fully developed hydrospires entirely of radial material.

G. Section about ¼ the length of the ambulacrum below the summit of the calyx.

H. Section just below half the length of the ambulacrum. The hydrospires are noticeably shorter and the longitudinal canal of the lancet has migrated inward.

I. Section near the lower end of the ambulacrum. The radials on their inner sides are about to encircle the tiny hydrospires.

tures are excavated in the lancets; these are the median groove and the internal longitudinal canal (nerve canal of some authors).

The median groove has the appearance of a V-shaped trough which notches the outermost median portion of the lancet. The groove begins slightly above the greatest diameter of the calyx and widens and deepens in the direction of the summit. The sides of the groove are crenulated normal to

the trend of the groove. At the point where the crenulations of the lancets come in contact with the crenulations of the deltoids, the markings coincide exactly indicating that they served the same purpose, that of the articulation of the ambulacral covering plates. The median groove levels off at the summit and then descends beneath the summit plates into the peristome.

The internal longitudinal canal which pierces the lancet extends from the extreme lower end of the lancet to the region of the summit where it divides to form the oral ring canal. The canal attains its greatest diameter within the deltoid area (Text-fig. 2E). Aborally, the canal decreases in size steadily and migrates from the center of the lancet lower and lower until, at the aboral end of the ambulacrum, it is quite small in size and very close to the innermost portion of the lancet (Text-figs. 2F–2I). Adorally (Text-fig. 2E), the canal ascends slightly (Text-fig. 2D), levels off (Text-fig. 2C), and then descends and divides (Text-fig. 2B). The two canals diverge and leave the lancet on their respective sides to pierce the deltoids (Text-figs. 1A,1B). The lancet at this point becomes progressively smaller (Text-fig. 2A) and soon disappears.

The oral ring canal.—As noted above, the internal longitudinal canals divide within the lancets, passing from the lancets to the adjoining deltoids. Each canal passes through the deltoid under or adoral to the divided spiracles and joins with the canal from the adjacent lancet, all of the joined canals forming a pentagonal ring (Pl. 129, fig. 5; Text-figs. 1A,1B). Within this pentagonal ring is inscribed another smaller ring which joins with it at the lengthwise middle point of the inner portion of the deltoid just under or inside the divided spiracles. The oral ring canal passes through the epideltoid on the anal side. Thus, the outer ring canal is interradial in position. Open connections exist between the two canals as shown (Text-figs. 1A,1B).

Side plates.—The side plates rest on the lancets and partially against the radials; they are small and number approximately 50 to 60 on each side of a lancet. In the lower two-thirds of an ambulacrum, as seen in cross section, their upper ends are in direct contact. In the upper one-third of an ambulacrum, the side plates are separated by the median groove and become more widely separated as the groove widens and deepens adorally. In the lower portion of an ambulacrum, the outer ends of the side plates rest with a slanted surface against the portion of the radials often referred to as the hydrospire plates. In the upper portion of an ambulacrum in the region of the deltoids, however, the side plates rest almost entirely on the lancet. In this area (Text-figs. 2B,2C), the lancet is lower in position relative to the deltoids and radials so that the side plates and lancet are joined on each side of the ambulacrum by the nearly straight, elevated lips of the radials and deltoids.

In well-preserved specimens, the upper, adoral portion of each side plate bears a prominent round mound or knob. Each mound or knob is crenulated with the crenulations running down and away from the summit of the knob. These markings represent the articulation marks of the brachiopods.

Outer side plates.—The outer side plates are located on the outer, adoral edge of the side plates, and there is one outer side plate for each side plate. Commonly, the outer side plates are approximately two-thirds the length of the side plates. The width of each outer side plate increases from the upper contact until, at the contact with the radial, it equals the width of the side plate. The aboral surface of the outer side plate slopes adorally until, at its junction with the lancet, its actual area has greatly diminished.

Brachioles.—Little is known concerning the brachioles. Meek & Worthen (1868) noted intact brachioles on a specimen which they identified with reservations as being *Orbitremites norwoodi* or possibly *O. norwoodi* var. *fimbriatus*. They stated that "this specimen . . . shows at least 30 (there are probably more) of these delicate, simple arms, arising from each pseudo-ambulacral area, and extending up so that the lower ones must be quite twice as long as the body. They are all composed of equal joints, about as long as wide."

In the past, most workers (Billings, 1871; Hambach, 1880; and Etheridge & Carpenter, 1886) have held that the brachiole

socket is situated between the hydrospire pores. Although no specimen of *Globoblastus norwoodi* having intact brachioles was available, the radial markings on the side plates are inferred to represent the articulation marks of the brachioles. As previously mentioned, the hydrospire pores of this species are not considered to bear any definite relation to the side plates and outer side plates although superficially they may appear to do so. The brachiole socket, therefore, may not be located in the customary position between the hydrospire pores. This is especially true in the upper parts of the ambulacra where the distance between the hydrospire pores nearly equals the width of the side plates.

Summit plates.—Because of inadequate preservation, little is known about the summit plates. In observed specimens the summit plates are very small and completely cover the peristome. They extend down each ambulacral sinus where they become the ambulacral covering plates. White (1863, p. 483) stated that

> "the whole central space between the summit tubes and the anal aperture, which is rather small, is overlaid with an integument of microscopic plates, entirely covering the central aperture, passing out between the bases of the tubes in a double series of plates, and was evidently continued far down the central grooves of the pseudambulacral fields, causing the crenulated appearance of those parts usually there, so that when perfect this integument was of a very sharply stellate form, the component plates being closely connected throughout, and so small that a space of a half a line square contains over thirty of them. They are prominent and distinct, but are somewhat irregular in size and arrangement."

This description appears to be accurate.

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JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1113–1116, PL. 131, 1 TEXT-FIG., NOVEMBER, 1961

AULOBLASTUS, A NEW BLASTOID FROM THE MISSISSIPPIAN BURLINGTON LIMESTONE

HAROLD H. BEAVER
Humble Oil & Refining Company, Houston, Texas

ABSTRACT—*Auloblastus clinei*, a large spiraculate blastoid from the upper Burlington of southwestern Missouri, differs from other blastoids in a combination of morphologic features, including the number of hydrospires, the radial-deltoid relationship, and the lack of a hydrospire plate. Two previously undescribed passageways, the lateral canals, are recognized; these canals parallel the median groove and are excavated into lancet and side-plate material along the lancet-side plate suture.

INTRODUCTION

SEVEN specimens of an undescribed large subspherical type of blastoid were obtained from the Mississippian Burlington limestone of southwestern Missouri in 1950. These are part of systematic blastoid collections made for studies under the direction of L. M. Cline of the University of Wisconsin. All of the specimens were collected from a zone near the top of the Burlington limestone in which *Pentremites elongatus* is common. *Globoblastus norwoodi* occurs slightly lower in the section (Beaver, 1961). One of the specimens is well preserved, several are partly deformed and weathered, and two are badly weathered, but they are suitable for morphologic studies. These specimens are described here so that all known blastoid genera can be included in the nearly completed blastoid section of the "Treatise of Invertebrate Paleontology."

Examination of the specimens was made with the aid of a binocular microscope; thin sections were made of the summit and the middle of the theca. Many of the detailed structures of the theca are observable on the weathered specimens.

R. M. Jeffords of Humble Oil & Refining Company critically reviewed the manuscript, and T. H. Miller of the same company photographed the specimens. R. O. Fay of the Oklahoma Geological Survey kindly offered suggestions on the taxonomy of the specimens.

SYSTEMATIC DESCRIPTION

Class BLASTOIDEA

Genus AULOBLASTUS, n. gen.

Type species: *Auloblastus clinei*, n. sp.

Theca subspherical; basals small, hidden in shallow basal cavity; radials long, overlap deltoids, nearly equal the height of the calyx, and turn in to form part of the basal cavity; deltoids small; spiracles 10, small, slitlike, excavated in lateral edges of the deltoid apices; not known if the posterior spiracles are separate from the anal opening; anal opening bordered by epideltoid adorally and hypodeltoid aborally; two large cryptodeltoids occur concealed beneath the hypodeltoid, one on either side of anal opening; ambulacra long, linear; lancets subhexagonal in section, pierced by central internal longitudinal canal; side plates small, handle-shaped, completely conceal lancet except adorally where the median groove exposes the lancet; in cross section one small lateral canal occurs along the suture between the lancet and each longitudinal series of side plates; outer side plates very small, generally occur along adoral abmedial margin of each side plate; no hydrospire plate; hydrospire pores present along entire length of ambulacrum, each pore bounded laterally by a side and outer side plate; hydrospires four on each side of ambulacrum.

Discussion.—*Auloblastus* differs notably from other blastoids of similar shape in its greater number of hydrospire folds and in a combination of other morphologic features (Table 1). In many respects the genus is morphologically intermediate between *Cryptoblastus* and *Schizoblastus*, particularly in the radial-deltoid relationship and the structure of the hydrospires.

AULOBLASTUS CLINEI Beaver, n. sp.
Pl. 131, figs. 1–10; Text-fig. 1

Description.—The specimens range from 1.8 cm. to approximately 2.3 cm. in height and from less than 1.8 cm. to about 3 cm. in width (the width of the smallest specimen

TABLE 1—COMPARISON OF DIAGNOSTIC MORPHOLOGIC FEATURES IN *Auloblastus* AND SOME OTHER BURLINGTON BLASTOIDS.[1]

GENUS	RADIAL-DELTOID RELATIONSHIP	NUMBER OF SPIRACLES[2]	HYDROSPIRE PLATE	NUMBER OF PLATES SURROUNDING ANAL OPENING	SPIRACLE-ANUS RELATIONSHIP	NUMBER OF HYDROSPIRE FOLDS PER AMBULACRAL SIDE	BASE
Auloblastus	RADIALS OVERLAP DELTOIDS	10?[3]	LACKING	4	POSTERIOR SPIRACLES AND ANUS PROBABLY SEPARATE[3]	4	MODERATELY CONCAVE
Globoblastus		5	PRESENT		ANISPIRACLE	2	GREATLY CONCAVE
Cryptoblastus		9		2 (4?)			SLIGHTLY CONCAVE
Carpenteroblastus			LACKING	2		2?	CONVEX
Lophoblastus	DELTOIDS OVERLAP RADIALS			2 (4?)		3	
Schizoblastus		10		2	POSTERIOR SPIRACLES AND ANUS SEPARATE	2	SLIGHTLY CONCAVE

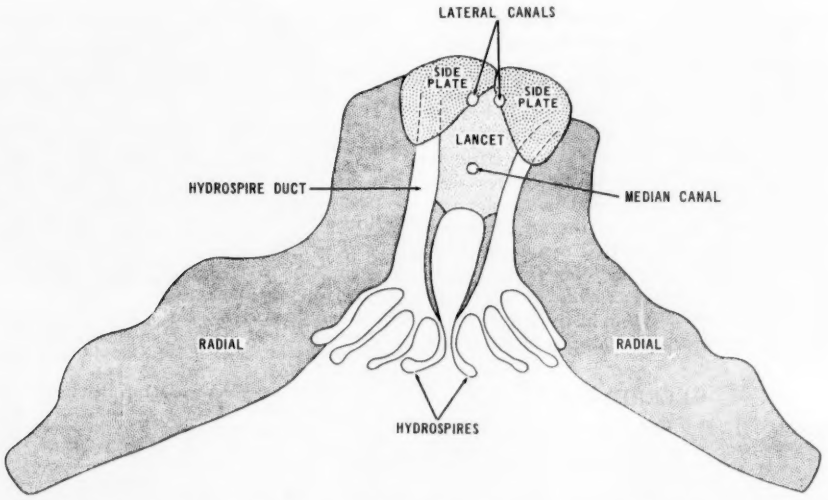
[1] *Partially based on data from Fay (1961).*

[2] *Number includes anispiracle when present.*

[3] *Posterior spiracles probably are not confluent with the anus.*

is not measurable). The shape of the theca varies from depressed globose to elongate ovate; its base is moderately concave. The basals are completely hidden in the basal cavity. The summit is depressed and is surrounded by the deltoids and the adoral portions of the ambulacra. The radials are long, nearly equaling the height of the theca. The radial bodies are small and border the basal cavity; the adoral extremity of each radial overlaps part of a deltoid near the summit. Well-preserved specimens have a pronounced longitudinal depression at the aboral extremity of each interradial suture due to several strong ridges or folds which converge on the suture in this area. The deltoids are small and triangular. A small spiracle opening is excavated into deltoidal and ambulacral material on either side of each deltoid, with the possible exception of those on the posterior side. The relationship of the posterior spiracles to the anal opening is not clearly determinable on the available specimens, but seemingly the spiracles and anal opening are not confluent. The anal opening is bordered adorally by the epideltoid; aborally the anal opening is bounded by the hypodeltoid. Concealed beneath the hypodeltoid and occurring on either side of the opening are two relatively large cryptodeltoids.

The ambulacra are narrow and nearly equal in length the distance from the summit to the basal cavity. The lancet plate is five sided in cross section with a flat adaxial (inner) surface; the shape (Text-fig. 1) is similar to that of *Globoblastus* and *Cryptoblastus*. A small round internal longitudinal canal which pierces the center of the lancet was noted in cross sections cut near the middle of the theca. The lancet is covered by side plates in the lower two-thirds of the ambulacrum, but in the upper third it is exposed along the median groove (food groove). The surface of the lancet is excavated for the articulation of each of the side plates, approximately 70 of which border each side of a lancet. The side plates are small and handle shaped; in cross section they rest at a steep angle on the lancet plate. The outer side plates are relatively large and occur in excavated areas along the margin of the side plates. It is often difficult to determine if the outer side plate is located along the adoral or aboral margin of the side plates, because part of each



TEXT-FIG. *1*—Drawing of an ambulacrum of *Auloblastus clinei*, n. sp., from a thin section cut just below the middle of the theca. Note the relatively large side plates and the four hydrospires beneath each side of the ambulacrum. ×15.

adjoining side plate may be excavated. Each side plate is bordered by one outer side plate.

Hydrospire pores occur near the abmedial margin along the entire length of each ambulacrum. Each pore is bounded by a side and outer side plate; the number of pores is directly proportional to the number of side and outer side plates. No hydrospire plate is present.

Two small canals, parallel to and lying one on each side of and obliquely adaxial to the median groove, are excavated into lancet and side plate material along the lancet-side plate suture. These canals, here named the lateral canals, have been observed on several weathered specimens on which the lancet was exposed and in cross section (Text-fig. 1). Longitudinally the lateral canals parallel the median groove from its aboral extremity to well beyond the radial-deltoid suture. The course of the lateral canals in the immediate vicinity of the mouth has not been observed. These canals have been illustrated previously (Etheridge & Carpenter, 1886) in the genera *Schizoblastus* and *Metablastus*, but the location of the canals on the lancet-side plate suture was not noted. Wanner observed the canals in *Thaumatoblastus longiramus* (1924) and in *Dipteroblastus permicus* (1940) and showed the location of the canals on the lancet-side plate suture. Analogus canals have been observed in thin sections of *Pentremites* from the Upper Mississippian Glen Dean limestone of southern Illinois (Beaver, 1954). Although the lateral canals have been illustrated previously in blastoid literature and seen occasionally in thin sections, they are not preserved commonly.

Four hydrospire folds occur beneath each ambulacral side (Text-fig. 1). These folds are small and similar structurally to those in *Schizoblastus*.

Occurrence.—*Pentremites elongatus* zone near the top of the upper Burlington limestone, Osagian series, Mississippian. Collections were made in the Ashgrove quarries near the State fish hatchery on U. S. Highway 65, about five miles south of Springfield, Greene County, Missouri.

Material.—Holotype, HC B235; paratypes, HC B236–B241. Upon completion of current studies, the holotype and figured specimens will be deposited in the U. S. National Museum.

Discussion.—*Auloblastus clinei* grossly re-

sembles *Globoblastus norwoodi* but is larger, has 10 rather than five spiracles, and lacks a hydrospire plate. It differs from *Cryptoblastus melo* (Cline, 1937) in being larger, in lacking a hydrospire plate, and in having a more concave base. *Auloblastus clinei* is similar to *Schizoblastus sayi* (Cline, 1936) in having the same number of spiracles, in lacking a hydrospire plate, and in having the same type of hydrospire structure; it differs in having long radials that overlie the deltoids instead of long deltoids that overlap the radials. *Auloblastus clinei* differs from all of the above species in having four rather than two hydrospire folds per ambulacral side.

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EXPLANATION OF PLATE 131

Auloblastus clinei Beaver, n. sp. All figures ×2 except *3–5,7,8*, which are ×10. All specimens from the upper part of the Burlington limestone in the Ashgrove quarries, U. S. Highway 65, approximately five miles south of Springfield, Greene County, Missouri.

FIGS. *1,2,5*—Interambulacral, aboral, and detailed ambulacral views of the holotype (HC 235); *5*, view near the aboral end of a weathered ambulacrum.

3,4,8—*3*, V-shaped median groove (food groove) of an ambulacrum and the parallel lateral canal on the right ambulacral side; *4*, the same specimen with the ambulacrum viewed from the side shows the lateral canal just below the median groove; and *8*, lateral canal along the right side of the photograph.

6—Ambulacral view with part of the lancet and side plates absent (HC 237).

7—Detailed view of the side and outer side plates at the level of the radial-deltoid suture (HC 237). The hydrospire pores are shown along the margins of the ambulacrum.

9,10—*9*, Oral view (HC 237); and *10*, (HC 236) the small spiracles are located along the lateral sides of the posterior right deltoid near its adoral extremity.

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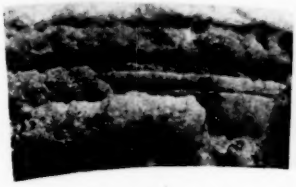

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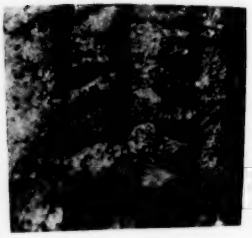

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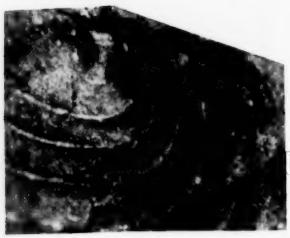

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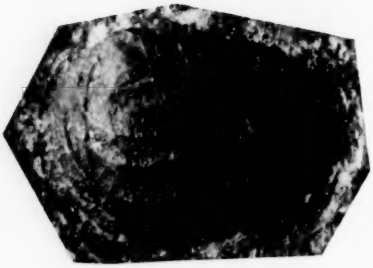

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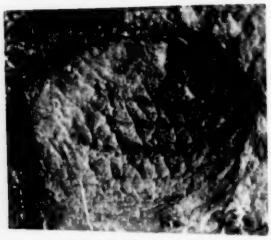

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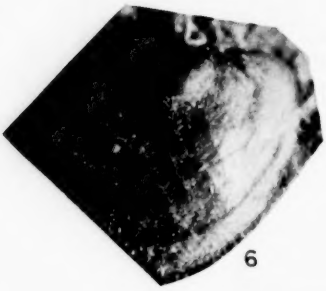

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JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1117–1120, PL. 132, NOVEMBER, 1961

PEMPHILIMNADIOPSEIDAE, A NEW FAMILY OF FOSSIL CONCHOSTRACANS

PAUL TASCH
University of Wichita, Wichita, Kansas

ABSTRACT—Restudy of Clarke's type material for *Estheria ortoni* brought to light an overlooked valve feature of critical taxonomic importance. This feature is the recurved posterior valve margin. This characteristic combined with that of a tubercle or spine on the initial valve in the same individual gives two distinct conchostracan shell features. These two features are the pemphicyclid (bearing an umbonal spine) and the limnadiopsid (with posterior recurvature of growth lines). This combination of valve features is the basis for the establishment of a new family, Pemphilimnadiopseidae, which includes Clarke's type material of *E. ortoni*. The tubercle or node that Clarke reported was found to be either a spine base or a hollow spine. The ontogenetic development of *Estheria ortoni* indicates that the pemphicyclid condition is ancestral to the paleolimnadiopsid condition. This obsertion must be reconciled with the older occurrence in the lower Mississippian of *Paleolimnadiopsis jonesi*, which has posterior recurvature but no umbonal spine. Either a pre-Mississippian pemphicyclid ancestor, presently unknown, gave rise to two distinct lines, the *ortoni* line and the *jonesi* line, or posterior recurvature of growth lines occurred independently in each of these lines.

INTRODUCTION

CLARKE'S original description and lithograph figures of *Estheria ortoni* from the lower barren coal measures of Carollton, Ohio (1900) were not quite complete. These figures were copied by Raymond (1946), obviously without restudy of the type material. He assigned Clarke's specimen to the genus *Pemphicyclus*.

Lioutkevitch (1941) had earlier assigned it to his new genus *Cornia*. This was also based on Clarke's published figures.

Both of these discussions of Clarke's species relied solely on the original published figures which are not accurate in detail.

LIMNADIFORM VALVES AND THEIR SIGNIFICANCE

Clarke's original descripton of his species noted:

> " . . . the primitive umbo is quite broad and quite bare not being raised to an apex or beak but being surmounted by a sharply defined, elongate, muscular node. Except for this node, the aspect of these small shells with bare umbonal region and sloping round-shouldered valves is much more like that which prevails in the living genus *Limnadia*."

Now this description bears correction. The phrase "sloping round-shouldered valves" obscures the posterior recurvature of the growth lines, the limnadiform aspect of the valves. This feature is covered by sediment in the material Clarke studied. Both this feature and the large umbo are beyond question *Limnadia*-like. Novojilov (1958) cites this as one of the main diagnostic features in his family Limnadiopsidae. He was unaware, however, of the posterior recurvature in *Estheria ortoni*, since he relied on Raymond's copy of Clarke's original figures.

EXPLANATION OF PLATE 132

FIGS. *1A,B*—*Pemphilimnadiopsis ortoni* (Clarke). *1A*, Left valve, NYSM 4444–1, ×12; and *1B*, same specimen enlarged, ×24.
2,3—*P. ortoni* (Clarke). *2*, One of Clarke's types, NYSM 44442–1, ×14; and *3*, another specimen on same slab as *2*, enlarged, NYSM 4442–2, ×24.
4—*P. ortoni* (Clarke). One of Clarke's types, NYSM 4441–1, ×15.
5,6—*P. ortoni* (Clarke). *5*, One of Clarke's types, NYSM 4443–1, ×12; and *6*, another specimen on same slab enlarged, NYSM 4443–2, ×20.

EVOLUTIONARY IMPLICATIONS

Novojilov (1958) erected a superfamily, Limnadiopseoidea, to include, among others, the familes Limnadiopseidae and Vertexiidae. Novojilov writes:

> Les tubercles obliques ou les épines sur les valves embryonnaires, caractérisent les genres *Gabonestheria*, *Echinestheria* et *Vertexia* réunis en une famille les Vertexiidae. Ces tubercles, ou *ces épines n'existent pas chez les genres* réunis dans les autres familles: Limnadiopseidae, etc. (my italics).

In other words, Novojilov knew of no example of a limnadiform valve (i.e., with posterior recurvature of growth lines) that also bore a tubercle or spine on the initial valve. This paper presents evidence that such an example does exist in Clarke's *Estheria ortoni*.

Estheria ortoni has characteristics linking it with both the Vertexiidae and Limnadiopsidae. The tubercle of the initial valve is a pemphicycliid-feature and hence of Vertexiidae relationship. The posterior recurvature of growth lines of the limnadiopsiid-type occurs in the adult portion of the valve and hence is of Limnadiopseidae relationship. Thus, the ontogenetic development of the individual passes through a pemphicycliid stage *prior to* a limnadiform stage.

When these observations are related to the fact that *Estheria ortoni* is of Conemaugh age, they indicate a pre-Pennsylvanian pemphicycliid-type ancestor for limnadiopsiids and the pemphicycliids.

Novojilov (1950) included a new genus *Belgolimnadiopsis* in his family Limnadiopseidae. The two species referred to this genus, *Estheria* (*Euestheria*) *stockmanii* Mailleux, 1939, and *E. coghlani* (1926) do not, however, have posterior recurvature of growth lines. Rather, the dorsal and posterior margins form an acute angle ("tronqué obliquement en arrière").

Since Mailleux' species is of lower Devonian age, it is important to stress that no Devonian limnadiopsiids are known at the present time which have recurved posterior growth lines. On Novojilov's chart (1958), the belgolimnadiopsiids are shown as ancestral to the paleolimnadiopsiids. However, the new evidence given in this paper shows that the pre-Pennsylvanian ancestor of *Paleolimnadiopsis* must have been a pemphicycliid-type lacking either the acute angle of *Belgolimnadiopsis* or the posterior recurvature of *Paleolimnadiopsis*. Furthermore, both paleolimnadiopsiid-types and pemphicycliid-types were derived from this ancestor.

Since it has been shown that pemphicycliid-types belong in the Vertexiidae, available data suggest that one line of the family Paleolimnadiopseidae and of the Vertexiidae were derived from a common ancestor, *Estheria ortoni*.

The argument may be raised that ornamentation differs in these forms. That is, while both the Paleolimnadiopseidae and Vertexiidae have alveolar ornamentation, *Estheria ortoni* has a radial-type sculpture, and pemphicycliids have punctate type. We must then establish a hierarchy of values to be attached to shell sculpture as contrasted to distinctive larval features and adult morphology (such as posterior recurvature of growth lines).

In the three choices indicated, larval features rank highest in terms of ontogeny, adult morphology next, and ornamentation third. As discussed amply elsewhere, American zoologists who are specialists on living conchostracans deny the ability to discriminate meaningfully genera and families on the basis of clam shrimp valve sculpture. In Novojilov's taxonomy, ornamentation takes precedence over larval features and adult morphology. The writer prefers the approach indicated above since it is closer to the available data on the biology of clam shrimps.

OTHER CONSIDERATIONS

Of note is the occurrence of both *Pemphicyclus* (larval spine type) (= *Cornia*) and *Paleolimnadiopsis* (posterior recurvature type) in the Oklahoma Wellington in association with leaiid-types. Similarly, *Estheria ortoni* slabs contain leaiid valves in addition to Clarke's species which has the dual feature of umbonal spinosity and posterior recurvature. Such nice equivalence in faunal associations and clam shrimp types in the Pennsylvanian of Ohio and the Permian of Oklahoma appears to the writer to argue for phylogenetic relationships rather than for parallel evolution or convergence.

NEW MEASUREMENTS ON *Estheria ortoni*

Table 1 provides data on eight specimens. These were not given in the original paper except in generalized form.

Clarke observed that on the slabs were specimens as small as 0.5 mm.–1.0 mm. in length with but three to seven concentric lines. These specimens are not given in Table 1 because they are buried under sediment and do not represent the true size. The size ranges from 1.50 mm. to 3.90 mm. for length and from 1.35 mm. to 3.60 mm. for height. Growth lines range from 4 to 18. Table 1 shows that the number of growth lines is not necessarily related to size as indicated by NYSM 4442-1 with five growth lines and NYSM 4444-2 with twelve, and yet both specimens have approximately the same length.

TABLE 1—DATA ON TYPES AND OTHER SPECIMENS OF *Estheria ortoni* CLARKE.

New York State Museum Number	Length (L) (mm.)	Height (H) (mm.)	Number of Growth Lines
*4444–1	3.90	3.60	18
4444–2	3.00	2.70	12
4444–3	1.50	1.30	6
*4442–1	3.15	2.10	5
4442–2	2.25	1.80	6
*4441–1	1.65	1.35	4
*4443–1	2.70	2.25	7
4443–2	2.40	1.35(?)	5

* Designates the type specimen. 4444–2, 4444–3, etc. indicate other unnumbered specimens on the same slab.

REASSIGNMENT OF *Estheria ortoni*

In light of the dual characters (umbonal spinosity and posterior recurvature) in Clarke's species, it is desirable to reassign it to a new family and genus. The uniqueness of this combination of characters, previously unreported in any other family, genus, or species, merits taxonomic recognition.

PEMPHILIMNADIOPSEIDAE, n. fam.

Conchostracans bearing a tubercle-type of spine on the initial valve and posterior recurvature of growth lines in adult portion of the valve.

PEMPHILIMNADIOPSIS, n. gen.
Pl. 132, figs. 1A,1B,3–6

Estheria ortoni CLARKE, 1900, New York State Mus. Rept., v. 1, p. 109–110, pl. 4, figs. 5–8.
Cornia ortoni LIOUTKEVITCH, 1941, Paleont. USSR, v. 5, pt. 10, p. 36.
Pemphicyclus ortoni RAYMOND, 1946, Harvard Mus. Comp. Zool., Bull., v. 96, no. 3, p. 266–267, pl. 4, figs. 3,4.

Supplementary description to complete Clarke's original description. Initial valve large, bears curved tapered hollow small spine which is depressed anteriorly above the spine base, situated in center of initial valve, straight dorsal margin, about two-thirds longer posterior to umbo than in front of umbo. Flattened flare in dorsal-posterior sector with apex at top of initial valve; narrow lateral slightly recurled portion of the flare margins dorsal border behind the umbo.

Measurements.—Table 1.

Type species.—New York State Museum 4444-1. *Pemphilimnadiopsis ortoni* (Clarke).

ACKNOWLEDGMENTS

I am indebted to Clinton F. Kilfoyle, curator of fossils at the New York State Museum, for the loan of Clarke's types of *Estheria ortoni*. My assistant, Robert Mallory, prepared the photographs.

ADDENDUM

The appearance in lower Mississippian time in Nova Scotia of a conchostracan with a recurved posterior margin, *Paleolimnadiopsis jonesi* (Jones), might lead one to ask why this specimen, the oldest of the known paleolimnadiopsiids, is not ancestral to the pemphicycliid? The writer relies on the evidence of ontogenetic development in *Estheria ortoni* Clarke, which indicates that the pemphicycliid condition is more ancient than the paleolimnadiopsiid condition.

It is indisputable that *Estheria ortoni* had a pemphicycliid ancestor. Hence it is also possible that the feature of posterior recurvature of growth lines occurred in this line independent of a similar development in the paleolimnadiopsiid line. As in all such matters pertaining to evolutionary trends based on fossil evidence, interpretations should be viewed as more or less plausible rather than conclusive.

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DATA ON SOME NEW LEONARDIAN CONCHOSTRACANS WITH OBSERVATIONS ON THE TAXONOMY OF THE FAMILY VERTEXIIDAE

PAUL TASCH
University of Wichita, Wichita, Kansas

ABSTRACT—The taxonomy of conchostracans bearing an umbonal spine, a larval feature, is reviewed. The family Vertexiidae is shown to embrace the genera *Echinestheria*, *Gabonestheria*, *Pemphicyclus* (reassigned here to *Cornia*), *Vertexia*, and *Curvacornutus*, n. gen. The original figures of types are reproduced.

Raymond's types of *Pemphicyclus* are restudied. The "tubercle" is found to be a "spine," adult valves are found to bear a flattered flare, and general morphology is similar to specimens lacking umbonal spines. The latter specimens are found in older Wellington beds.

The possibility of dimorphism in *Pemphicyclus-Gabonestheria* is considered.

Isaura (*Euestheria*) *harveyi*, Form A, based on a restudy of ornamentations, is reassigned to the subgenus *Lioestheria*, since all evidence of polygonal sculpture is lacking. The one new genus, *Curvacornutus*, and the three new species *C. prima*, *C. modesta* and *Gabonestheria dickinsoni* are described and illustrated from the Kansas Wellington.

The inferred evolutionary significance of larval shell spinosity and the condition of dorsal margin serration is discussed.

SOME CONCHOSTRACANS WITH UMBONAL SPINES

SEVERAL fossil conchostracans bearing umbonal spines (usually referred to as "tubercles" or "nodes") have been described. These include the following: *Cornia* Lioutkevitch, 1939; *Estheria* (*Pemphicyclus*) *gabonensis* Marlière, 1950, (referred to the genus *Gabonestheria* Novojilov 1958; *Estheria* (*Echinestheria*) *marimbensis* Marlière, 1950, referred to the genus *Echinestheria* Marlière by Kobayashi in 1954; *Pemphicyclus* Raymond, 1946; and *Vertexia* Lioutkevitch, 1939.

Collections from the Leonardian of Kansas and Oklahoma were found to contain at least two of these genera, *Pemphicyclus* and *Gabonestheria*, and a new genus, *Curvacornutus*. Since new data have thus become available on conchostracans bearing spines on the umbo, the taxonomic status of the family is re-examined.

Pemphicyclus RESTUDIED

Study of Raymond's type specimens (Harvard MCZ 4782–4785) brings to light pertinent new data. It also permits publication of new photographs of his types to replace the unusable ones published when the genus was described.

The holotype, *Pemphicyclus laminatus*, is ovate to subrectangular, bears six to seven growth zones, and on subrectangular valves has a narrow flattened flare of the same type found in *Isaura* (*Euestheria*) *harveyi*, Form A (Pl. 133, fig. 10). Other paratypes (MCZ 4783–4784) bear fewer growth lines.

Twenty specimens measured on the slabs bearing Raymond's types show a size range from 0.70 mm. to 3.90 mm. in length and 0.50 mm. to 3.00 mm. in height. The bulk of the specimens are less than 2.00 mm. in length and less than 1.50 mm. in height. The position of the umbo varies from central to subcentral in the more ovate forms (Pl. 134, figs. 3,5,6) to anterior in subrectangular forms (Pl. 133, figs. 8,10). At ×150 magnification, only scattered punctae can be observed between growth lines.

The tubercle appears to be a mere nipple-type node in the center of the umbo on the circular valves. In some cases, though not in all, this is clearly due to erosion. In other specimens, it is a regular minute spine. This is especially true where the valve is subrectangular in shape.

It should be borne in mind that all of Raymond's specimens came from the Wellington of Noble County, Oklahoma. The writer's collections from Kansas show

pemphicycliids with clearly developed spines even in the more ovate valves (Pl. 134, figs. 3,5,6).

Of the two conchostracan-bearing horizons in the Annelly gypsum, the uppermost or the C_9 horizon, bears specimens with a flattened flare and no spine. These belong to *Isaura* (*Euestheria*) *harveyi*, Form A. They are reassigned to the subgenus *Lioestheria*.

Some ten feet above the top of the Annelly, pemphicycliids are first encountered in the C_1 horizon of Harvey and Sedgwick Counties. As far as this evidence throws light on the origin of pemhicycliid types, it suggests that they were derived from the *Isaura* (*Lioestheria*) *harveyi* line. The joint occurrence of both flattened flare and same general morphology, together with an umbonal spine in pemphicycliids, argues for such a relationship. It is of interest in this connection to note that conchostracans with umbonal spines do not appear to persist vertically above the older part of the upper Wellington. They were absent in collections from the upper Wellington through the Ninnescah.

The data discussed earlier also show that in every feature, from nature of spine to position of umbo and valve shape, a range of possibilities is realized in the same population. This result is to be expected in natural populations. Nevertheless, the fact must be emphasized if we are to understand the scope and limits of this genus and its type species.

RECENT COLLECTIONS OF *Pemphicyclus*

The writer's collections from the Wellington of Kansas and Oklahoma contain numerous individual valves bearing a central umbonal spine. The umbonal position varies from subcentral to anterior depending upon the configuration of the valve. Casts of the interior of valves bear a minute conical depression in the center of the umbo that corresponds to a hollow conical spine on the original valve. Thus it appears that Raymond's "tubercle" is actually a spine, although in some instances the spine was either undeveloped or preserved as an erosional remnant.

These specimens are generally less than 2.0 mm. in length and range from subovate to nearly circular in shape. The number of growth lines also is variable and exceeds thirteen in number in several specimens.

All specimens in the writer's collections that fit the above description are assigned to *Pemphicyclus laminatus* Raymond. Overlap or coincidence in all characters adequately support this assignment.

Cornia LIOUTKEVITCH

Lioutkevitch in 1939 assigned his Tartarian conchostracans bearing an umbonal spine to a new genus, *Cornia*. He noted that Clarke's species *Estheria ortoni* was close to his type specimen and reassigned the former to his new genus.

In 1946, Raymond, unaware of Lioutkevitch's new genus, assigned Clarke's species *Estheria ortoni* to his newly erected genus *Pemphicyclus*. This last genus, as noted above, was based primarily on material from the Oklahoma Wellington. The position of *E. ortoni* Clarke is now under study.

The holotype of *Cornia melliculum*, is subovate, bears up to thirteen or fourteen growth lines, and has an average length of 2.0 mm. and an average height of 1.8 mm. Its sculpture is punctate. The position of the umbo appears from the photograph to be more nearly anterior than subcentral.

It should be noted that the type specimen is distorted. One can trace an oblique rise on the valve that starts at the postero-dorsal margin and proceeds inward and ventrally to about the seventh or eighth growth line. The valve is also crushed in a vertical line at two places on the valve below the umbo. When this configuration is restored to the original condition, it corresponds with those found among the Wellington pemphicycliids.

This last point is of some importance since Novojilov (1958) concluded "D'après le contour des valves le genre *Cornia* doit être placé dans la famille des Lioestheriidae." This position appears to be untenable in light of the apparent shell damage and breaks in the type specimen.

If we compare several characters of *Cornia* such as size, umbonal spine, umbonal position, and growth lines with those of *Pemphicyclus* they will be seen to overlap. Therefore, *Cornia* should supplant *Pemphicyclus* since it has priority. Kobayashi

(1954) independently reached this conclusion and Tasch (1956, Table 1) concurred. Study of the Wellington collections, Raymond's type material, and a restudy of Lioutkevitch's paper reaffirms this assignment.

Echinestheria AND *Gabonestheria*

In the field all valves with umbonal spines were tentatively classified under *Echinestheria annellya*. Subsequent study revealed that both pemphicycliid and gabonestheriid types were present in the collections. This section will treat with the gabonestheriids.

When Marlière (1950) described *Estheria* (*Echinestheria*) *marimbensis*, he observed "Cette form se rapproche à première vue du *Pemphicyclus* Raymond." Kobayashi elevated the subgenus *Echinestheria* to generic status. In doing so he recognized the distinctive character of the large conical subcentral larval spine. However, he was in error in thinking that *Cornia* and *Pemphicyclus* had only a tubercle-like umbonal elevation. While both *Pemphicyclus* and *Echinestheria* bear an umbonal spine, not only do the spines differ in size, nature, and position, but the two genera have different shell configurations.

A second subgenus, *Pemphicyclus*, was erected by Marlière. In this way he designated his species as a pemphicycliid type. He described the spine as a projecting node or a hollow and round tubercle included in the antero-dorsal angle.

Novojilov gave Marlière's species generic status in *Gabonestheria*. He stressed the fact that the elongated tubercle borne on the embryonic valve was from one-third to two-thirds the shell size and that the spine axis was transverse to the shell.

Specimens in Tasch's Wellington collections show that the spine position within the antero-dorsal angle and its large size are the critical characters. These distinguish such specimens from others with spines central, subcentral, or anterior in position which are distinctively smaller in length and less robust. The latter specimens belong to *Pemphicyclus*, reassigned as noted earlier to *Cornia*.

In this connection, the specimens referred to *Gabonestheria sibirica* by Novojilov are plainly not gabonestheriids since they have small to minute spines centrally located on the umbo. They belong under *Cornia* along with the pemphicycliids and are here so reassigned.

TABLE 1—OCCURRENCE OF *Pemphicyclus* AND *Gabonestheria* VALVES IN THE WELLINGTON FORMATION OF KANSAS

Locality	Bed Number	*Pemphicyclus* (= *Cornia*)	*Gabonestheria*
		Number of Valves*	
Elmo IV	13	5	4
Elmo IV	14	4	18
Ann. VIII	2	6	1
Ann. IA	14	only†	none
Ann. VIIIA	5	only†	none
Sedgwick I	1 (lower ½)	none	only†

* Numerals indicate number of valves found together on same bedding plane.
† "Only" indicates that all valves found belonged to the given genus.
"None" indicates the total absence of any valves of the respective genus.

Pemphicyclus AND *Gabonestheria*

In the Wellington collections at hand, *Pemphicyclus* (= *Cornia*), and *Gabonestheria* individuals are sometimes found on the same bedding plane. Table 1 shows the relationship found at several localities.

It can be seen from Table 1 that there are different manners in the occurrences of the two genera. (1) Valves of both may occur on the same bedding plane in equal numbers. (2) A greater or lesser number of valves of either genus may occur on the same bedding plane. (3) Only one genus may occur on the bedding plane to the complete exclusion of the other. These occurrences raise the possibility that valves assigned to the two different genera may be dimorphs of the same genus and species. In that event, difference in numbers of valves may express the male/female ratio.

A study of reports on living forms tends to strengthen this theory. For example, Mattox (1950) described a new species as *Caenestheriella gyneica* based solely on females. No males were known. Spandl (1925) showed that in warm countries males of *Leptestheria dahalacensis* (Ruppel) pre-

dominated and constituted up to seventy-five percent of the population. Elsewhere, this figure decreased to as little as ten percent for males. The predominance of males or females among other living conchostracan populations are known. The writer's collections of *Cyzicus mexicanus* showed an equal number of males and females in one Sedgwick County (Kansas) pond and a greater number of males in an adjacent pond. In a third nearby pond, females outnumbered males.

The question as to whether specimens of *Pemphicyclus* and *Gabonestheria* represent examples of dimorphism of the same pemphicycliid species, *P. laminatus*, cannot be determined to the writer's complete satisfaction based on the evidence at hand. The evidence at hand is regarded as suggestive. Pending such reopening of the question, the writer recognizes Novojilov's genus *Gabonestheria*. All valves in the Wellington collections bearing a large spine rising from the umbo situated in the antero-dorsal angle of the valve are thus assigned to a new species *Gabonestheria dickinsoni*.

FAMILY VERTEXIIDAE KOBAYASHI

Novojilov raised Kobayashi's subfamily Vertexiinae to family status. This family was to embrace *Echinestheria*, *Gabonestheria*, and *Vertexia*. The family is said to be characterized by alveolar ornamentation. On this basis *Pemphicyclus* was excluded. The tubercle in *Pemphicyclus*, in his interpretation, represents "un caractère de convergence avec une autre famille de conchostraca les Bairdestheriidae."

Novojilov considers that *Cornia* belongs in the Lioestheriidae. Contour of the valves is the feature that influenced his opinion. As discussed above, overlap in morphology and valve characters between *Cornia* and *Pemphicyclus* make this argument unacceptable to the writer.

The family Vertexiidae then embraces *Echinestheria*, *Gabonestheria*, *Pemphicyclus* (= *Cornia*), *Vertexia*, and *Curvacornutus*, n. gen. We may characterize the family as embracing all fossil conchostracans where the larval condition of umbonal spinosity is present.

Novojilov assigns both generic and family importance to ornamentation throughout his taxonomy of fossil conchostracans. Kobayashi, showed that living estheriids (a) have various kinds of sculpture in the interspaces between growth lines, (b) have sculpture that is not always the same throughout ontogenetic development of any given individual, and (c) have sculpture not confined to a given genus or group of genera. The writer's independent study of this work supports this interpretation.

Mattox (1957), a leading investigator of living conchostracans, found that the shell of *Cyzicus mexicanus* ranged from "granulated-to-ridged" in appearance. He expressed his opposition to the use of ornamentation as a device to separate species and genera in fossil forms. Most of Novojilov's taxonomy is based on sculpture. In this sense, the writer is largely in agreement with Mattox. The use of sculpture as a taxonomic device should be employed with care, and certainly should never be used to differentiate between conchostracan families.

The observations of Kobayashi, Mattox, and others can well be illustrated by reference to fossil conchostracans. Jones (1857), for example, showed three distinct types of sculpture for the fossil genus *Estheriina*.

In light of such data on living and fossil conchostracans, it is unwise to insist on ornamentation in fossil clam shrimps as a primary means for all taxonomic assignments. As discussed elsewhere umbonal characteristics such as size, position, and spinosity, relating as they do to the larva stage of the individual, may prove to be of more value in discriminating the Vertexiidae.

Novojilov excluded *Pemphicyclus* from the family because of ornamentation. He then had to explain the similar umbonal spinosity found in it and in other members of the family. To accommodate this problem he suggested that umbonal spinosity was a convergent character in *Pemphicyclus*. This argument is effectively diminished by the occurrence of gabonestheriid and pemphicycliid valves on the same bedding planes in the Wellington. The likelihood of convergent evolution from within a contemporaneous population of a small pond situation, often no larger than a puddle, is negligible.

EVOLUTIONARY SIGNIFICANCE OF LARVAL SHELL SPINOSITY

The development of spinosity of the larval shell with the broad range of expression to be found in the Vertexiidae indicates that this feature is genetically variable.

In turn, one must question whether some adaptive advantage may not be associated with this variability of what originally may have been a morphologic expression of an interior muscle attachment spot or a purely ornamental feature. Loop development may have had some advantage in permitting individuals to attach more firmly to or rest on bottom vegetation while feeding. The writer has observed individuals nesting among aquarium weeds for long periods of time.

The conical type of spine in *Gabonestheria* and *Echinestheria* may have served to assist the animal in movement through dense bottom vegetation without getting trapped. The minute umbonal spine of pemphicycliids in turn may be the ancestral condition.

The marked spinosity of *Vertexia* includes not only the umbo, but the dorsal ends of successive growth bands which develop spinous apophyses. The probable function here appears to be somewhat different. In one of the living species studied by the writer, *Caenestheriella belfragei*, a serrated dorsal margin is present. Under high power it is seen to be a subdued expression of the *Vertexia* condition.

Dorsal serration which presents a rasping margin may have a selective advantage to individuals with such shells. The writer has observed aquaria clam shrimps resting on or near the bottom, with the dorsal margin in the bottom mud or cradled in weeds, while the appendages projecting through the gaping ventral end moved rapidly to circulate the water and contained food particles. A serrated margin may have some attachment or stabilizing advantage in such situations.

Few looped and curved spinous individuals were found among a larger number of conical or pemphicycliid tubercle types. This suggests that these few were mutant individuals from the gabonestheriid and pemphicycliid populations. It also appears that this tendency to form a curved umbonal spine was unsuccessful in an evolutionary sense since no subsequent populations are known to be characterized by it.

Dorsal apophyses of growth bands are found in living genera such as *Limnadopsis*. Hence, we may view this Paleozoic tendency as having selective advantage among varied clam shrimp populations.

The feature, larval shell spinosity, has been accorded generic rank by most workers and, in the writer's opinion, merits it. As the discussion above indicates, such a feature appears to have more value as an indicator of an evolutionary tendency than the usual variations in shell configuration or test sculpture.

ACKNOWLEDGMENTS

I am indebted to Harry B. Whittington for the loan of Raymond's types of the genus *Pemphicyclus* on deposit at the Harvard Museum of Comparative Zoology.

Field and laboratory work that provided data for this report was supported by research grants NSF G-4150 and G-7320.

Photographs of Raymond's types and other specimens were prepared by my assistant, Robert Mallory.

SYSTEMATIC PALEONTOLOGY

Genus CORNIA Lioutkevitch

Plate 133, fig. 12

Cornia LIOUTKEVITCH, 1937, Soc. Pal. de Russie, Ann., v. 9, p. 59–70, pl. 9, fig. 11.
Cornia LIOUTKEVITCH, 1939, Atlas of Leading Forms of Fossil Faunas of the USSR, Permian 6, p. 192–193, pl. 46, fig. 5.
Cornia LIOUTKEVITCH, 1941, Paleontology of the USSR, v. 5, p. 36–37, pl. 3, figs. 4,5.
Pemphicyclus KOBAYASHI, 1954, Jour. Fac. Sci., Univ. Tokyo, sec. 2, v. 9, pt. 1, p. 135.

A small spine or tubercle rises from the center of the initial valve. The sculpture is punctate. The valve shape varies from subovate to subrectangular. The umbonal position varies from subcentral to anterior.

Type species.—*Cornia papillaria*. (*C. melliculum*, 1941, designated by Lioutkevitch as the type species.)

CORNIA LAMINATUS (Raymond)

Pl. 133, figs. 2,7,10

Pemphicyclus laminatus RAYMOND, 1946, Harvard Mus. Comp. Zool., Bull., v. 96, no. 3, p. 265, pl. 3, fig. 12; pl. 4, figs. 1,2.
Cornia laminatus KOBAYASHI, Jour. Fac. Sci., Univ. Tokyo, sec. 2, v. 9, pt. 1, p. 135.

TABLE 2—DISTRIBUTION AND SIZE OF *Pemphicyclus* (=*Cornia*) *laminatus* RAYMOND IN SEVERAL WELLINGTON BEDS IN KANSAS (n=27)

County	Locality	Bed Number	Length (l) (mm.)	Height (h) (mm.)	Ratio (l/h)
Harvey	Ann. IA	14	1.10	0.72	1.51
	Ann. IC	5	1.75	1.50	1.16
	Ann. IIIA	3	1.20	1.05	1.14
		3	1.75	1.35	1.29
	Ann. IV	8	1.37	1.12	1.22
		8	1.02	1.00	1.02
		8	1.27	0.93	1.30
	Ann. VIIA	5	0.87	0.75	1.16
		5	0.92	0.75	1.23
	Ann. VIIIA	2	0.45	0.42	1.05
		2	0.75	0.69	1.08
		2	0.82	0.75	1.10
		2	0.82	0.55	1.50
		2	0.50	0.47	1.05
		2	2.12	1.92	1.10
Dickinson	Elmo III	13	1.35	1.05	1.28
		13	2.40	2.25	1.06
		13	1.65	1.65	1.00
	Elmo IV	13	1.35	1.05	1.28
		13	1.33	1.25	1.06
		13	2.05	1.40	1.39
		13	0.97	0.80	1.21
		13	1.87	0.97	1.82
		14	1.45	1.00	1.41
		14	1.62	1.25	1.30
		14	1.75	1.62	1.07
		14	1.90	1.17	1.61

EXPLANATION OF PLATE 133

FIGS. *1*—*Curvacornutus modesta*, Tasch n. sp. Left valve of holotype. Note oblique disposition of spine across umbo and of spine's moderate curvature, ×29.

2,7,10—*Pemphicyclus laminatus* Raymond [=*Cornia laminatus* (Raymond)]. *2*, Ovate left valve, paratype, MCZ 4784, ×11; *7*, like figure *2*, right valve, paratype, MCZ 4783, ×45; *10*, subovate right valve, holotype, MCZ 4782, ×17. *2,7*, and *10* are from the Wellington formation, Noble County, Oklahoma.

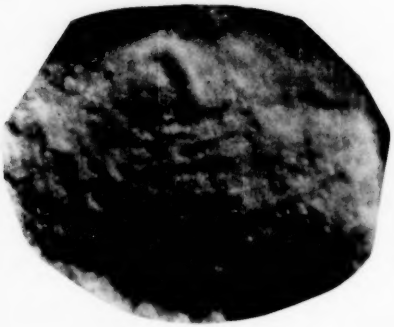
3—*Curvacornutus prima*, Tasch, n. sp. Left valve, ×20, Elmo IV, Bed 13.

4,8,9,11—*Cornia laminatus* (Raymond). *4*, Subovate right valve showing tubercle, ×15; *8*, adult, right valve, showing more than 13 growth lines, the spined larval condition, ×14, Elmo III, Bed 13; *9*, adult, left valve, subovate, ×15, Elmo IV, Bed 14; and *11*, note marked spine development, ×17, Elmo IV, Bed 14.

5—*Estheria* (*Pemphicyclus*) *gabonensis* Marlière [=*Gabonestheria gabonensis* (Marlière). Marlière's original figure, ×29.

6A,B—*Gabonestheria dickinsoni* Tasch, n. sp. *6A*, Left valve, paratype, ×37, Elmo IV, Bed 14; and *6B*, left valve holotype, ×38, Elmo IV, Bed 14.

12—*Cornia melliculum* Lioutkevitch. The original figure enlarged. Right valve, ×25.



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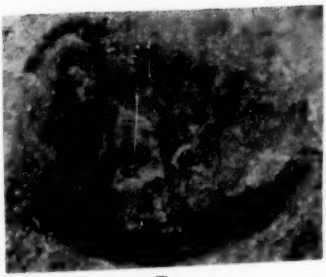

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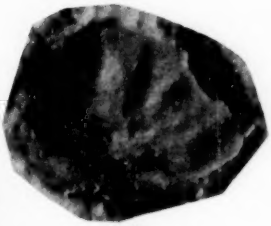

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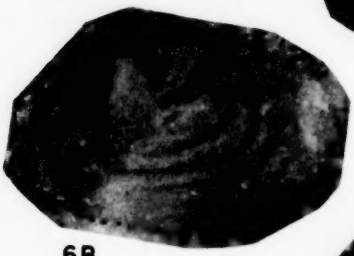

6B

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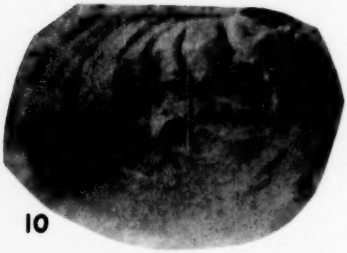

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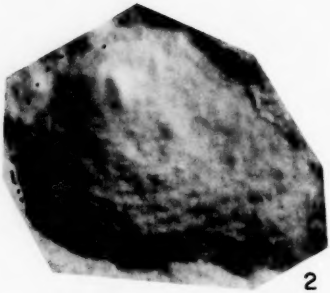
1A



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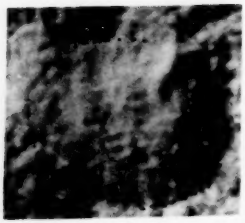

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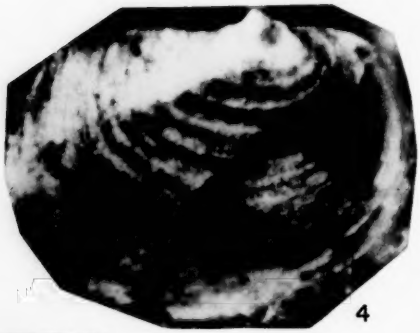

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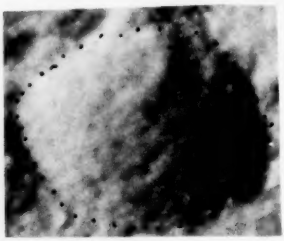

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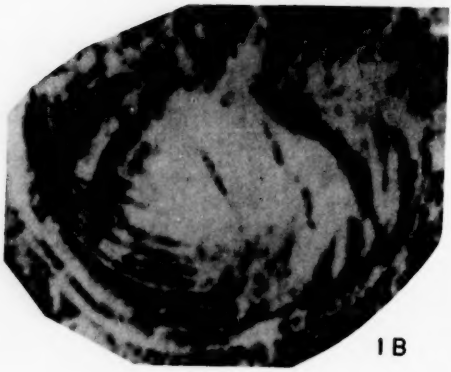

1B

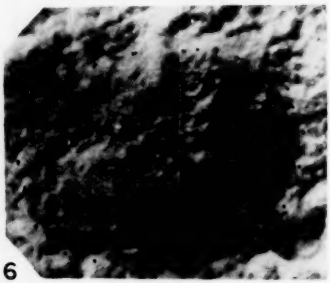

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TABLE 3—DISTRIBUTION AND SIZE OF *Gabonestheria dickinsoni*, n. sp. IN SEVERAL WELLINGTON BEDS IN KANSAS (n = 27)

County	Locality	Bed Number	Length (l) (mm.)	Height (h) (mm.)	Ratio (l/h)
Sedgwick	Sedg. I	1 (lower ½)	1.25	1.00	1.25
		1 (lower ½)	3.30	2.10	1.54
Harvey	Ann. IC	4	4.10	3.00	1.36
	Ann. IV	8	1.12	0.80	1.39
	Ann. VIII	2	1.00	0.72	1.37
Dickinson	Elmo III	13	2.12	1.07	1.98
		13	1.20	1.05	1.14
		13	0.95	0.72	1.21
		13	1.12	0.95	1.21
		14	1.50	1.07	1.39
		14	1.75	1.37	1.27
		14	1.42	1.12	1.27
		14	1.92	1.75	1.10
		14	1.92	1.70	1.13
		14	1.32	1.22	1.08
		14	1.29	1.05	1.21
		14	1.50	1.10	1.36
		14	1.10	0.80	1.37
		14	1.82	1.62	1.12
		14	1.12	0.75	1.50
		14	1.55	1.50	1.03
		14	1.65	1.12	1.46
		14	1.62	1.12	1.44
		14	1.70	1.05	1.61
		14	2.00	1.40	1.42
		14	2.00	1.12	1.78
		14	0.67	0.49	1.37

Valves vary in shape from nearly circular to subovate. Minute hollow conical spine occurs in center of initial valve. Umbonal position is subcentral for more circular valves and anterior for subovate types. Growth line number is variable. Size generally less than 2.0 mm. in length.

Genus GABONESTHERIA Novojilov
Pl. 133, fig. 5

Estheria (Pemphicyclus) gabonensis MARLIÈRE, 1950, Mus. Congo Belge, Ann., Sci. Géol., Sér. 8, v. 6, p. 32–33, pl. 3, figs. 1–3.

Gabonestheria gabonensis NOVOJILOV, 1958, Service d'information Géol. du, Bur. Recherches Geol et Minieres, Ann., no. 26, p. 111–112, pl. 2, figs. 28,29.

EXPLANATION OF PLATE 134

FIGS. *1A,B*—*Vertexia tauricornis* Lioutkevitch, *1A*, Original figure, holotype, left valve, ×26; and *1B*, imprint of right valve, allotype, ×26.

2—*Curvacornutus modesta* Tasch, n. sp., paratype, ×28, Ann. IIIA, Bed 3.

3,5,6—*Cornia laminatus* (Raymond) Three photographs deliberately out of focus to emphasize the umbonal spine. *3*, Right valve, ×19, Ann. IIIA, Bed 3; *5*, ovate-type valve, right valve, ×43, Ann. VII, Bed 5; and *6*, subovate valve, ×25(?), Ann. VII, Bed 5.

4—*Estheria (Echinestheria) marimbensis* Marlière [(=*Echinestheria marimbensis* (Marlière) Kobayashi, 1954)]. Original figure, right valve spine, represented by truncated lower portion, adult valve, ×21.

Round, tapered, projecting tubercle on initial valve, positioned in antero-dorsal sector of shell.

Type species.—*Estheria* (*Pemphicyclus*) *gabonensis* (Marlière).

GABONESTHERIA DICKINSONI
Tasch, n. sp.
Pl. 133, figs. 6a,6b

Valves variable from ovate to subovate. The umbonal area in the antero-dorsal sector is bulbous even where compressed; the initial valve gives rise to a robust conical spine that has a length greater than one-half the valve height. The number of growth lines, is variable.

Discussion.—The ratios of length to height for *Gabonestheria gabonensis* for four specimens range from 1.14 to 1.41. The length of these specimens varies from 1.61 mm. to 4.40 mm. The ratios of length to height ranges from 1.03 to 1.98 in the new species. This is true even though only two specimens out of 27 were greater in length than 2.12 mm. Neither of these two specimens accounts for the lower or upper limit of the range in ratio. In other words, a greater variation in morphology of valves obtains in the young population represented by the new species than in Marlière's young and adult specimens taken together.

Another way in which it differs is in the nature of the umbonal spinosity. Marlière's "bouton saillant" or projecting tubercle was described as "creux" and "arrondi." The new species has a clearly developed, large, broad-based, tapering, conical spine. This spine extends in the compressed state up to or quite close to the dorsal margin. In the writer's opinion, Marlière's "bouton" is a spine base.

Elsewhere in the present paper the occurrence of the new species and *Pemphicyclus* (= *Cornia*) *laminatus* is discussed. The possibility of dimorphism was raised earlier. Since populations of both genera (*Gabonestheria* and *Pemphicyclus*) in the Wellington were dominantly 2.00 mm. or less, these populations may be viewed as assemblages of young valves. Thus, in ponds where both genera occurred *shortly after hatching of the eggs*, the two distinct types of larval spinosity developed. Such contemporaneity of larval development in terms of size and spinosity may strengthen the argument for dimorphism.

Repository.—University of Wichita, Department of Geology. Holotype, W.U. 101.00; paratypes, W.U. 101.10, 101.11.

Genus CURVACORNUTUS Tasch, n. gen.

Conchostracans with a distinctive looped or curved spine rising from the initial shell of the anterior umbo.

Type species.—*Curvacornutus prima* Tasch, n. sp.

CURVACORNUTUS PRIMA Tasch, n. sp.
Pl. 133, fig. 3

The subovate valve bears a small looped spine on the initial valve. Spine is situated in depressed condition within the antero-dorsal sector of the valve. Six growth lines extend from the ventral margin to the flattened umbo.

The length measures 2.37 mm., the height measures 1.48 mm., at the length/height ratio is 1.60.

Discussion.—The new genus is found on the same bedding plane as gabonestheriids. This suggests a close relationship between individuals belonging to each of these genera. The rarity of occurrence of looped individuals suggests that it is a mutant derived from the gabonestheriid-pemphicycliid population. The tendency towards looped spines appears not to have been successful since it is not expressed in any known subsequent fossil population.

Occurrence.—Dickinson County, Kansas (Elmo IV, Bed 13).

Repository.—University of Wichita, Department of Geology. Holotype, W.U. 102.00.

CURVACORNUTUS MODESTA Tasch, n. sp.
Pl. 133, fig. 1

A curved spine rising from the initial valve has its root near the dorsal margin and in a subcentral position. The spine is elongated and disposed almost diagonally across the umbonal area.

The length is 2.11 mm., the height is 1.48 mm., and the length/height ratio is 1.42.

Discussion.—This species differs from *Curvacornutus prima* in lacking loop-development of the spine, and in the dorsal

submedian origin of the spine root. The curvature and elongation of the spine are variable.

Repository.—University of Wichita, Department of Geology. Holotype, W.U. 103.00, locality Ann. IV, Bed 8; paratype, W.U. 103.10, locality Elmo IV, Bed 13; paratype, W.U. 103.11, locality Ann. IIIA, Bed 3.

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JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1130–1136, PLS. 135–136, 1 TEXT-FIG., NOVEMBER, 1961

PENNSYLVANIAN FUSULINIDS FROM WARD HUNT ISLAND

M. L. THOMPSON
Illinois State Geological Survey, Urbana

ABSTRACT—The following Pennsylvanian fusulinids are described and illustrated from Ward Hunt Island, located a few miles north of Ellesmere Island and on the south margin of the Arctic Ocean: *Ozawainella? arctica* Thompson, n. sp., *Pseudostaffella wardensis* Thompson, n. sp., *Fusulinella zelleri* Thompson, n. sp., *Wedekindellina lata* Thompson, n. sp., and *Fusulina huntensis* Thompson, n. sp. These are the first Pennsylvanian fusulinids to be described and illustrated from the northern Arctic region of Canada. The rocks from which they were collected are correlated with the middle part of the Desmoinesian Series of the central United States.

ROCKS of upper Paleozoic age have been known for many years from the northern islands of the Arctic in the Eastern Hemisphere and in the Western Hemisphere (Troelsen, 1950; Dunbar, 1955; Harker & Thorsteinsson, 1960). However, only a few of their contained fossils have been described in detail.

Dr. Edward J. Zeller visited parts of the north area of Ellesmere Island and neighboring islands, including the U. S. Air Force Cambridge Research Center, where he had an opportunity to examine some of the surface areas and to collect rock samples that he later sent to me for study. One of these sets of samples was obtained from the highly inclined limestones exposed within the ice flowage on the west side of the saddle at the U. S. Air Force Cambridge Research Center on the northwest end of Ward Hunt Island. Ward Hunt Island is a land area of a few square miles, located within the Ward Hunt Ice Shelf northwest of Disraeli Fjord and only a few miles to the north of Ellesmere Island (Text-fig. 1).

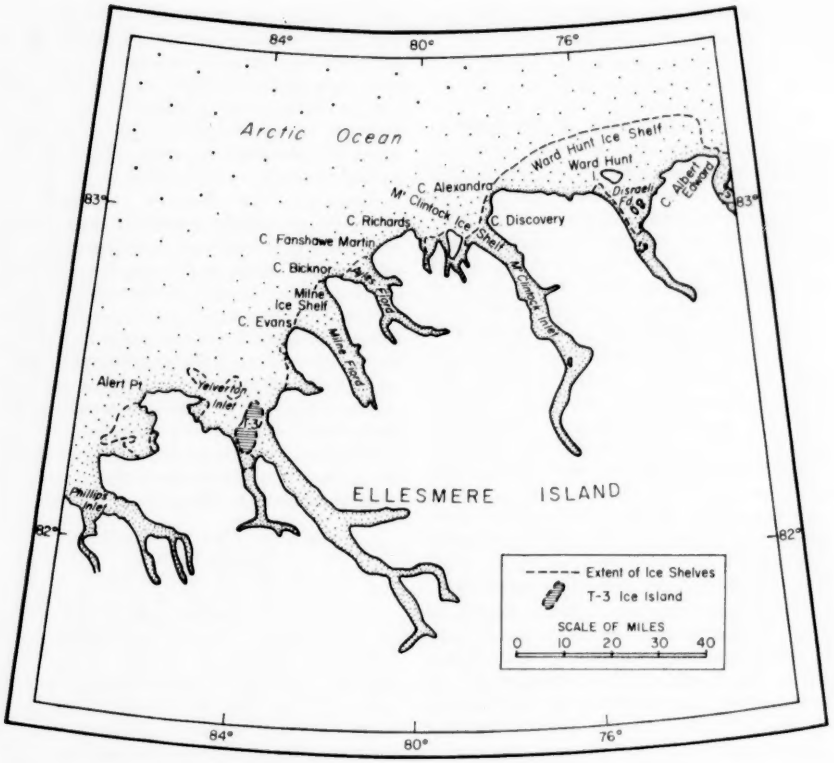
Troelsen (1950) gave a summary discussion of the historical geology of northwestern Greenland, Ellesmere Island, and Axel Heiberg Island, and stated that rocks of Pennsylvanian age were known only from exposures on the east coast of Canyon Fjord immediately south of the eightieth parallel on Grinnell Land and more than 200 miles south by slightly west of Ward Hunt Island. He described the section of rocks exposed there and listed the fossils, including fusulinids, that had been obtained from it. The fusulinids were listed as including species of *Fusulina*, *Fusulinella*, *Wedekindellina*, *Ozawainella*, and *Staffella*. This association would indicate a Desmoinesian age for the Canyon Fjord rocks. We do not have reports of Pennsylvanian fusulinids from any other islands of the Arctic region of Canada, although Pennsylvanian fusulinids have been described or reported from several other areas farther south in Canada (Thompson & Verville, 1950; Thompson, Pitrat & Sanderson, 1953; McGugan & Rapson, 1960).

Dunbar (1955) described one of the largest Arctic upper Paleozoic faunas known from east Greenland, about 600 miles east and south of Ward Hunt Island. He included a stratigraphic summary of former published reports from the Arctic, and he compared the Greenland faunas with those from Spitzbergen (Svaldbard), Novaya Zemlya, and other Arctic localities.

Harker & Thorsteinsson (1960) described numerous Permian fusulinids and other fossils from the north edge of Grinnell Peninsula, about 500 miles south by west of Ward Hunt Island. They also discussed the stratigraphy and regional geology of this area of northern Canada.

Several dozen thin sections have been prepared of the limestone samples Dr. Zeller collected. All of them contain numerous specimens of fusulinids of a number of generic groups. Because of the importance of fusulinids in determining the age of upper Paleozoic rocks, the presence of several highly diagnostic genera on Ward Hunt Island seems worthy of a special consideration at this time.

Fusulinids have been known from east Greenland for many years. However, practically no detailed information has been published concerning their affinities or de-



TEXT-FIG. *1*—Map showing some features on the north end of Ellesmere Island. Reproduced in part from Arctic, v. 13, no. 1, 1960, by permission of A. P. Crary and the Arctic Institute.

tailed shell features. Although only a minor amount of stratigraphic information is available about the fusulinids I am studying, they supply considerable information about the stratigraphic age of the upper Paleozoic limestone observed in the frozen grounds on the surface of Ward Hunt Island.

The fusulinid fauna from Ward Hunt Island contains representatives of *Ozawainella?*, *Pseudostaffella*, *Fusulinella*, *Wedekindellina*, *Fusulina*, and *Eoschubertella*. Many of the species of these genera resemble closely species that have been described from the central United States, and the fusulinid association on Ward Hunt Island seems to demonstrate that the containing rocks are of about the same age as rocks of the Cherokee Group of Iowa, Missouri, Kansas, and Oklahoma.

So far as we are able to determine, this is the most northerly locality from which Pennsylvanian fossils have been found. Of similar interest was the discovery of fusulinids in Patagonia, on the south tip of South America (Cecioni, 1955), where fusulinids of about the same age as those found on Ward Hunt Island have been reported.

The illustrated type specimens are deposited with the Illinois State Geological Survey and are filed under the catalog numbers with the prefix 22P.

SYSTEMATIC PALEONTOLOGY

OZAWAINELLA? ARCTICA
Thompson, n. sp.
Pl. 135, figs. 1–8

The shells of *Ozawainella? arctica* Thompson, n. sp., are small in size and distinctly discoidal in shape. The entire shell seems symmetrical. However, the peripheral area of many specimens of larger size seems nonsymmetrical or even possibly slightly evolute. This latter feature cannot be determined with certainty. Shells of six volutions measure 0.52 to 0.61 mm. in length and 1.01 to 1.24 mm. in width, giving form ratios of 0.44 to 0.52 for three specimens. The lateral slopes are distinctly convex. However, the lateral surfaces become concave toward the periphery in the fifth or sixth volution to maturity. The periphery of the shell is narrowly rounded in the first four to five volutions but it becomes angular as the shell grows beyond the fifth volution. The form ratios of the first through the seventh volution of one specimen are 0.69, 0.51, 0.49, 0.49, 0.57, 0.52, and 0.51, respectively.

The proloculus is small and spherical in shape and has an outside diameter that averages about 39 microns for four specimens. The heights of the chambers above the periphery of the shell average about 33, 50, 79, 119, 154, and 180 microns for four specimens.

The chambers are short throughout the shell, and as a result the septa are closely spaced. There are 9, 19, 20, and 33 septa in the first through the fourth volution of one specimen. The septa extend forward sharply and come in contact with the spirotheca of the preceding whorl at an inclined angle. The septa curve in an arch in front of the chambers. The septa are totally unfluted along the antetheca.

The detailed structure of the septa and of the spirotheca was not determined. The spirothecal structure is presumed to be like that of *Ozawainella* because nothing was observed to indicate that it is different. The tunnel has a narrow flat bottom that is tangent to the sharply angular periphery of the shell. Its upper margin defines an inverted V-shaped opening in the septa. The tunnel angle was not measurable. Massive chomata occur throughout all parts of the shell except for the first one or two volutions. They are more than half as high as the chambers and are spread to the polar areas of the shell. The flat base of the tunnel on the periphery is almost normal to the surface of the volution. The chomata deposits extend up the septa for considerable heights.

Remarks.—The massive asymmetrical chomata, the highly discoidal shell shape, the size of the shell, and the shape and attitude of the septa of this species resemble closely those features of *Reichelina cribroseptata* Erk, the type species of the genus *Reichelina* Erk. However, no evidence has been observed to indicate that the specimens I am studying have later or gerontic stages of the shell that tend to uncoil, as has been described for *R. cribroseptata*.

Occurrence.—This species is abundant in all parts of the limestone samples which I have studied from Ward Hunt Island.

PSEUDOSTAFFELLA WARDENSIS
Thompson, n. sp.
Pl. 135, figs. 9–16

The shell of *Pseudostaffella wardensis*, n. sp., is small and subspherical in shape, with distinctly umbilicate polar areas and broadly rounded lateral surfaces in the center of the shell. Specimens of seven to eight volutions measure 1.1 to 1.3 mm. in axial length and 1.2 to 1.4 mm. in width. The form ratio of the shell is of near the same value from the fourth volution to maturity. The form ratios of the first through the eighth volution of the holotype are 1.20, 1.10, 1.00, 0.94, 0.92, 0.90, 0.91, and 0.88, respectively.

The spirotheca is moderately thick for the genus, and it contains thick upper and lower tectoria. Although most species of *Pseudostaffella* in America do not have distinct diaphanotheca in the spirotheca, a rather thick clear layer occurs below the tectum in this species from the third volution to maturity.

The chambers are short in the inner part of the shell, and they gradually increase in length to the mature stage of the shell. The septal counts of the first through the seventh volution of one specimen are 10, 14, 14, 19, 20, 27, and 30, respectively.

Chomata extend from the edges of the tunnel to the polar ends in all except the outermost volution. They are more than half as high as the chambers laterally from the tunnel and decrease only slightly toward the polar ends. The tunnel angle measures about 16, 19, 20, and 26 degrees in the fourth through the seventh volution, respectively.

Remarks.—The most distinctive features of this species are its thick spirotheca with distinct diaphanotheca in the outer volutions and its massive and broad chomata throughout the shell. Its shell is larger at maturity than are other American species. This species resembles some of the Asiatic and European species of *Pseudostaffella*, including *P. ozawai* (Lee & Chen). Somewhat similar forms of *Pseudostaffella* are found in the lower part of the Cache Creek Series of British Columbia and in the Norquay formation of Alberta (McGugan & Rapson, 1960).

Occurrence.—Specimens of *Pseudostaffella wardensis* are abundant in limestone on the northwest end of Ward Hart Island and are present throughout the limestones studied.

FUSULINELLA ZELLERI Thompson, n. sp.
Pl. 135, figs. 17–20

Fusulinella zelleri Thompson, n. sp., is small in size, distinctly fusiform in shape, and inflated in the middle of the shell. It has slightly concave to straight lateral slopes, bluntly pointed outer ends, and straight axis of coiling. Shells of seven volutions measure about 3.5 mm. in length and 1.4 to 1.7 mm. in width, giving form ratios of 2.1 to 2.4. The shape of the shell changes slightly with growth of the individual. The form ratios of the first through the seventh volution for two specimens are about 1.7, 1.8, 1.9, 1.9, 2.0, 2.1, and 2.2, respectively.

The spirotheca has thick upper and lower tectoria that remain of near the same thickness throughout the shell. The moderately thick diaphanotheca is present from the third or fourth volution to maturity. The spirotheca of the inner three volutions seems composed only of thick upper and lower tectoria and a tectum.

The septa seem of about normal spacing for the genus. However, in the first two and one-half volutions the chambers remain short and the septa are closely spaced. Beginning with the third volution, the septa become more widely spaced. The septal counts of the first through the fifth volution of one specimen are 12, 15, 19, 17, and 17, respectively. The septa are about normal to the spirotheca, but they are inclined slightly forward. Although the septa are plane throughout most of the shell, they are slightly fluted in the extreme polar areas.

The shell expands slowly with growth, and the increase in the height of the chambers is about uniform. Heights of the chambers of the first through the sixth volution of a typical specimen are 40, 44, 48, 76, 84, and 139 microns, respectively. The outside diameter of the proloculus measures 120 to 137 microns in three specimens.

The tunnel expands from a circular cross section near the proloculus to a moderately wide path in the sixth volution. The tunnel angle measures 21, 24, 25, and 30 degrees in the third through the sixth volution of two specimens. The chomata are narrow, with steep tunnel and poleward slopes. Although the chomata have steep sides, they remain almost half as high as the chambers throughout most of the shell.

Remarks.—Several shell features of *Fusulinella zelleri* differ from the shell features of most other species of *Fusulinella*. The differences in *F. zelleri* are its narrow high chomata, the rather sudden development of diaphanotheca in its spirotheca, and its very slight degree of septal fluting. However, this species seems rather typical of the genus in other respects.

Occurrence.—*Fusulinella zelleri* is scarce in the samples of limestone studied from Ward Hunt Island in association with species of *Ozawainella?*, *Pseudostaffella*, *Wedekindellina*, *Fusulina*, and an undescribed form of *Eoschubertella*. Only about half a dozen specimens of this species have been found among my numerous thin sections.

This species is named in honor of Dr. Edward J. Zeller of the University of Kansas who collected all the samples on which this study is based.

WEDEKINDELLINA LATA Thompson, n. sp.
Pl. 136, figs. 1–7

The shell of *Wedekindellina lata* is small in size and elongate fusiform in shape. It has pointed polar ends, straight axis of coiling, and slightly convex lateral slopes. Shells with seven volutions measure about 3.4 mm. in length and 1.01 to 1.12 mm. in width, giving a form ratio of 3.0 to 3.2. The shell remains nearly the same shape throughout its growth, and the form ratios of the first through the seventh volution of three specimens average 2.1, 2.2, 2.5, 2.5, 2.7, 3.0, and 3.2, respectively.

The proloculus is relatively large and spherical in shape. Its outside diameter averages 115 microns in three specimens. The septa are closely spaced in the first two to three volutions, and they gradually become more widely spaced in the outer volutions. One specimen has 11, 13, 15, 18, 21, 23, and 24 septa in the first through the seventh volution, respectively. The septa are plane in the central regions of the shell but are slightly irregular in the extreme polar areas. There is no distinct septal fluting in any part of the shell, so far as can be determined. However, regularly spaced undulations bring some septa in contact at the base of the chambers of outer volutions. The heights of the chambers in the first through the sixth volution average 35, 36, 53, 63, 85, and 114 microns, respectively, in three specimens.

The spirotheca is thick and is composed of a tectum, diaphanotheca, and moderately thick upper and lower tectoria. Distinct diaphanotheca are observed in the second volution to maturity.

The tunnel is relatively wide, and its path is about straight. Averages of the tunnel angles in the third through the sixth volution are 27, 28, 31, and 33 degrees, respectively. The chomata are low and highly asymmetrical, with steep tunnel sides and low broad lateral slopes. The chomata extend laterally to join with the axial fillings that fill the end zones of all chambers except those of the last part of the outer volution.

Remarks.—*Wedekindellina lata* is the most abundant of the fusulinids I have observed from Ward Hunt Island. In fact, the shells of this form are more abundant than all the other fusulinids found there. This species is a typical representative of the genus *Wedekindellina*, and it resembles most of the others. The most distinctive of its features are its large spherical proloculus, its slightly inflated uniform shell, and its moderately light axial fillings.

Occurrence.—*Wedekindellina lata* is abundant in all parts of the limestone samples studied from Ward Hunt Island.

FUSULINA HUNTENSIS Thompson, n. sp.
Pl. 136, figs. 8–16

The shell of *Fusulina huntensis*, n. sp., is elongate fusiform in shape, with pointed

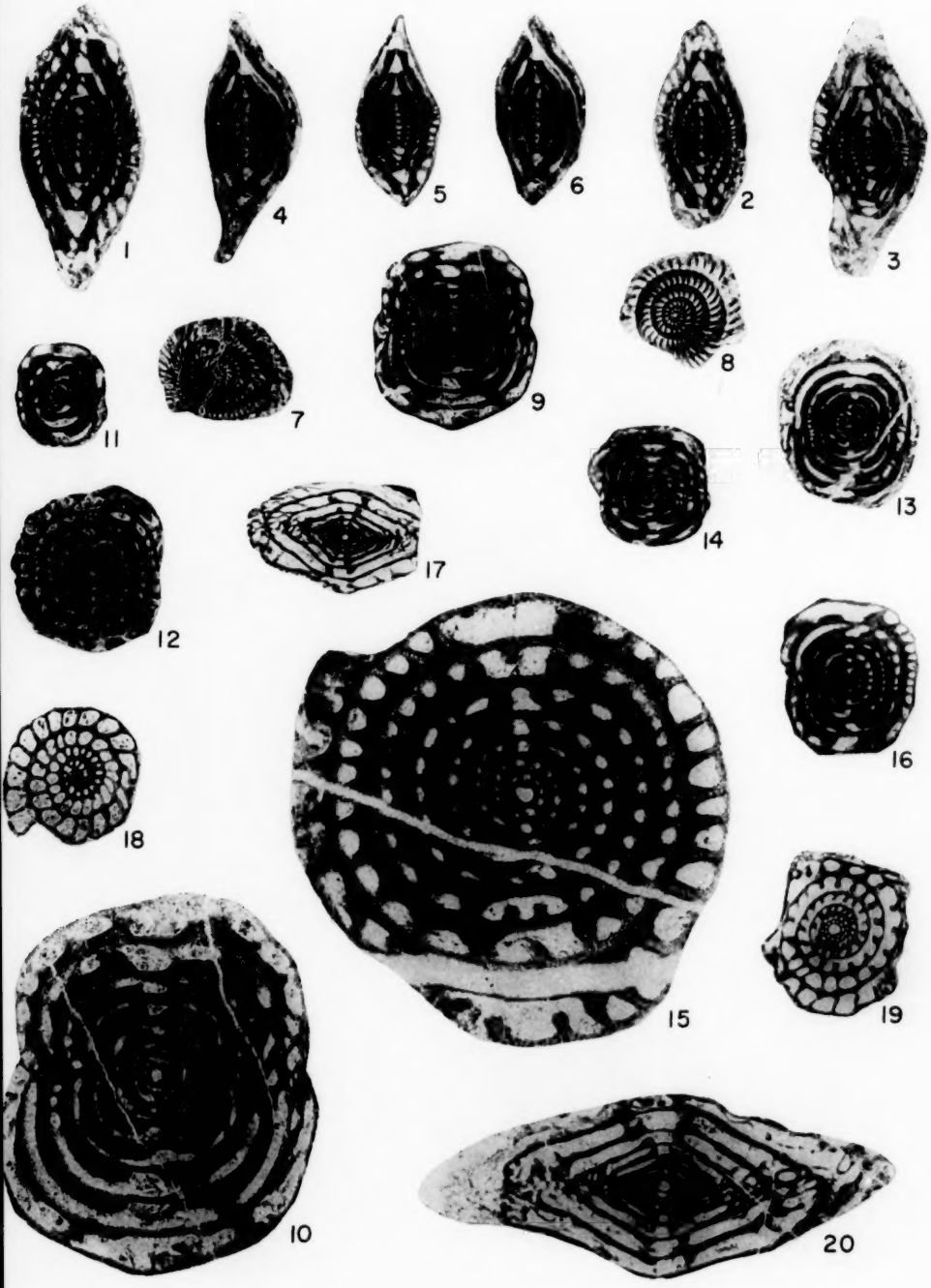
EXPLANATION OF PLATE 135

All illustrations on this plate are unretouched photographs.

FIGS. *1–8*—*Ozawainella? arctica* Thompson, n. sp. *1*, Axial section of the holotype; *2,3*, axial sections of paratypes; *4,5,6*, tangential sections of paratypes; *7*, faulted sagittal section of a paratype; and *8*, sagittal section of a paratype; *1* is ×40 and *2–8* are ×30.

9–16—*Pseudostaffella wardensis* Thompson, n. sp. *9,10*, Axial section of the holotype, ×20 and ×40; *11,13,14,16*, near centered tangential sections of paratypes, *11* ×30, *13,14,16* ×20; *12*, slightly oblique axial section of a paratype, ×20; and *15*, oblique section of a paratype, ×50.

17–20—*Fusulinella zelleri* Thompson, n. sp. *17*, Axial section of a paratype, ×10; *18*, parallel section of a paratype showing spirothecal structure, ×20; *19*, sagittal section of a paratype, ×20; and *20*, sagittal section of the holotype, ×20.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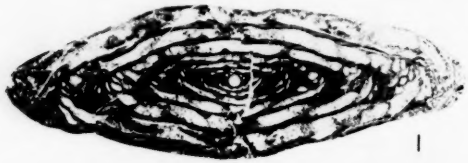
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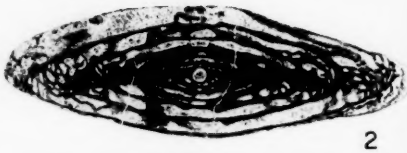
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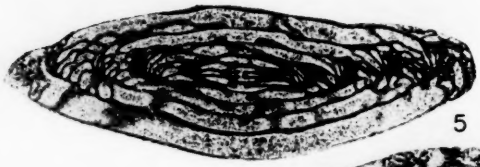
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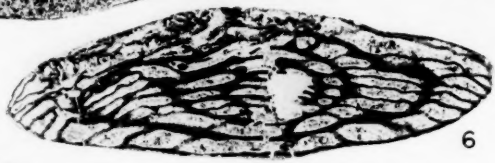
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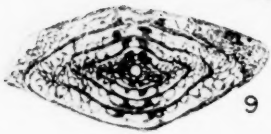
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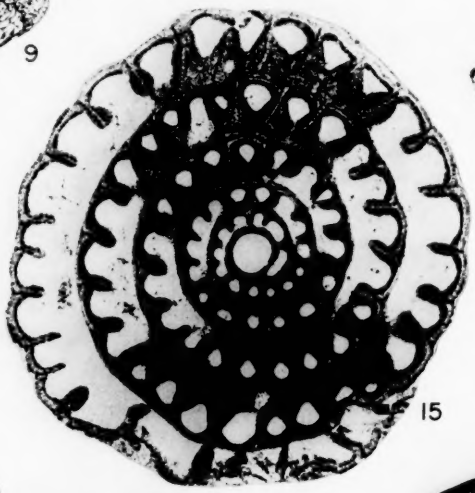
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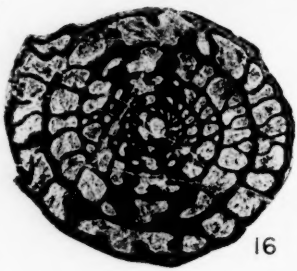
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polar ends, inflated central region, and slightly concave lateral slopes. Mature shells of five to six volutions measure 1.7 to 2.4 mm. in width and 3.8 to 5.7 mm. in length, giving form ratios of 2.2 to 2.4. The first volution is inflated and has a form ratio slightly greater than unit value, but the form ratio of mature shells is as great as 2.4. Averages of the form ratios of the first through the sixth volution of four specimens are 1.2, 1.6, 1.8, 2.0, 2.2, and 2.3, respectively.

The proloculus is relatively large and spherical in shape. It has an outside diameter of 190 to 260 microns, averaging 226 microns for seven specimens. The shell expands slowly and about uniformly. Averages of the heights of the chambers in the first through the sixth volution of seven specimens are 63, 86, 125, 187, 234, and 238 microns, respectively. The heights of the chambers are less in the center of the shell, and they increase toward the polar ends.

The spirotheca is composed of upper and lower tectoria, tectum, and diaphanotheca. The diaphanotheca is distinct from the second volution to maturity. It seems somewhat thicker than normal for this genus in the fifth and sixth volutions. The spirotheca is thickest in the regions of the tunnel; it becomes thin poleward.

The septa are thin in the center of the shell and are moderately widely spaced. The septal counts of the first through the fifth volution of three specimens are 11, 15, 19, 23, and 25, respectively. The septa are narrowly and highly fluted throughout the length of the shell, and they are brought in contact by the fluting for about half the heights of the chambers to the edges of the tunnel.

The tunnel is wide and its path is nearly straight. The tunnel angles of the second through the fourth volution average about 27, 27, and 31 degrees, respectively. The chomata are narrow and high with steep tunnel sides and steep poleward slopes. In fact, the chomata are nearly three-fourths the heights of the chambers.

Remarks.—*Fusulina huntensis* is a typical form of *Fusulina* much like many of those that occur in the middle part of the Desmoinesian in the central part of the United States where they are associated with abundant faunas of *Wedekindellina* and *Pseudostaffella* such as are found on Ward Hunt Island. The degree of fluting of this form also indicates an age near that of the upper Cherokee. The only shell feature that does not entirely fit into this general interpretation is the somewhat thick diaphanotheca found in the outer volutions of *F. huntensis*.

Occurrence.—Specimens of *Fusulina huntensis* are common throughout the limestone samples studied from Ward Hunt Island, where they are associated with all of the fusulinids described in this paper.

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EXPLANATION OF PLATE 136

All illustrations on this plate are unretouched photographs.

FIGS. *1–7*—*Wedekindellina lata* Thompson, n. sp. *1,3*, Axial sections of paratypes; *2*, axial section of the holotype; *4*, sagittal section of a paratype, *5,6*, tangential sections of paratypes; and *7*, section tangent to penultimate volution showing degree of fluting at the base of this volution; all ×20.

8–16—*Fusulinia huntensis* Thompson, n. sp. *8*, Tangential section of a paratype; *9–11*, axial sections of paratypes; *12*, axial section of the holotype; *13,14,15*, sagittal sections of paratypes; and *16*, oblique section of a paratype; *8–14* are magnified ×10, *15* is magnified ×40, and *16* is magnified ×20; *15* and *16* show details of spirothecal structure.

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JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1137–1142, PL. 137, NOVEMBER, 1961

NEW PHOSPHATIC BRACHIOPODS FROM THE SILURIAN OF OKLAHOMA

H. A. IRELAND
University of Kansas, Lawrence

ABSTRACT—Acetic acid residue of samples of Silurian Chimney Hill Limestone from Oklahoma contain phosphatic brachiopods that are described as two new genera, *Artiotreta* and *Acrotretella*, and two new species, *Artiotreta parva* and *Acrotretella siluriana*. All of these are referable to the Order Neotremata. They may be referable to the family Acrotretidae, or they may represent a new family. Hundreds of perfectly preserved specimens of both valves of *Artiotreta* were examined, and all of them measured near 0.50 mm. in maximum diameter. All evidence indicates that they represent mature specimens and that they are not juvenile specimens. Only 24 *Acrotretella* were found. Specimens were collected in three localities two to ten miles apart. Both of the species discussed are unusual because of the complete preservation of valve interiors which generally are not seen, though casts and molds are common.

THE solution of hundreds of samples of Silurian limestones in hydrochloric acid has revealed many arenaceous Foraminifera from beds in the Arbuckle Mountains of Oklahoma. Insoluble residues contain two new genera and two new species of an unnamed new family of phosphatic brachiopods that are less than 1 mm. in size. However, the phosphatic brachiopods were not revealed until acetic acid was used on these same limestones in search for conodonts. The new brachiopods were first discovered in 1950 and have been found since then in other exposures of Silurian limestones from Oklahoma.

The brachiopods were found in the middle part of the Chimney Hill Member of the Hunton Formation about 300 yards east of Tulip Creek where U. S. Highway 77 crosses the Chimney Hill on the south side of the Arbuckle Mountains in southern Oklahoma. They have also been collected from similar beds on Honey Creek and on Lick Creek on the north side of the Arbuckle Mountains ten to twelve miles from the type locality. It is of interest that a few specimens of one of these were derived from Silurian beds in Herefordshire, England (Ireland, 1958) in the type area of the Silurian described by Murchison.

At least 900 specimens of both dorsal and ventral valves of one species are in the residue samples. There seems no question that they are phosphatic and that they are Neotremata. Growth lines, pedicle openings, interiors and exteriors of both valves, median septa, and other features are unusually well preserved. Adult specimens are remarkably uniform in size, and they measure between 0.40 and 0.50 mm. across the subcircular area. Their uniformity and maximum size indicate that they represent adult specimens. Thickened shells and distinct growth lines beyond the periphery of dozens of specimens show gerontic features. The protegulum of young individuals are present. The perfection of preservation displays every feature of morphology, and both valves are preserved with about equal numbers. A few specimens with joined dorsal and ventral valves demonstrate the relation of the separated valves.

The second species is based on eight ventral valves and sixteen dorsal valves. It is much more conical and larger and has a greater range in size. Valves of both species are thin and fragile and must be handled carefully.

Little is known about the dorsal septum in many Neotremata. However, exposure of the well developed septa in these two new forms is unusual and forms a basis for new information. Casts and prints of many poorly preserved forms that have been described previously indicate that much more complex and ramified septa and muscle attachments exist in pre-Silurian species. Acetic acid solution of samples from type localities of many described Neotremata might provide new information on the

character and variation of dorsal septa and the interiors of both dorsal and ventral valves.

The brachiopods from the Chimney Hill are found in a fine-grained relatively pure limestone. They are associated with conodonts and fragile arenaceous Foraminifera composed of fine silt-size agglutinated tests. A kilogram of bulk sample rarely yields more than a few grams of residue, but it may be composed of as much as 25 percent microfossils of various classifications that may number thousands of specimens. The discovery of this new type of brachiopod should be an incentive for more paleontologists to use acid residues as a laboratory technique.

Thanks are extended to A. J. Rowell of Nottingham University, England, for examination of specimens sent to him, and for his comments and help.

Type specimens are deposited with the U. S. National Museum.

SYSTEMATIC DESCRIPTIONS

It may be that these new genera belong to a new subfamily, but there is little basis for placing them outside the superfamily of Acrotretacea. The lack of muscle scars, consolidation and simplification of the pseudointerarea, the position and character of the dorsal median septum, and size indicate considerable difference from known families of the Acrotretacea. There is a lack of knowledge on the evolution of Neotremata between the Lower Ordovician and Silurian, and the forms described here may be representative of a declining lineage of recognized families.

Genus ARTIOTRETA Ireland, n. gen.

The shell is subcircular, is thin and fragile, and is composed of chitinophosphate or calciphosphate. The ventral valve is convex and almost hemispherical, with a slightly conical appearance. Foramen is well developed, round, and slightly anterior and below the apex, with slight callouses around the opening. The surface has fine distinct growth lines, the growth is holoperipheral, and the protegulum is not apparent. The posterior area has obvious but broad shallow pseudointerarea, no intertrough, and a slight but distinct notch at the hinge line. The growth lines are continuous across the pseudointerarea. The dorsal valve is slightly convex with prominent protegulum and very fine distinct growth lines. The interior is smooth, with no muscle scar depressions observable. It has a prominent median unbranched septum, beginning near the center of the valve and sloping upward as a blade to a high terminus near the anterior margin.

Type species.—*Artiotreta parva* Ireland, n. sp.

ARTIOTRETA PARVA Ireland, n. sp.
Pl. 137, figs. 1–12

The shell is subcircular, is thin and fragile, and is composed of chitinophosphate or calciphosphate. The ventral valve is convex and almost hemispherical, with a slightly conical appearance. Foramen is well developed, round, and slightly anterior and below the apex with slight callouses around the opening. The surface has fine distinct growth lines, and the growth is holoperipheral. The protegulum is not apparent. The posterior has obvious but broad shallow pseudointerarea with no intertrough. Growth lines are continuous across pseudointerarea. There is a slight but distinct notch at the hinge line. The dorsal valve is slightly convex, with a prominent protegulum defined by fine growth lines. It has a distinct but short poorly developed hinge line. The interior is smooth with no muscle scars apparent. A prominent unbranched median septum begins near the center of the valve and slopes upward as a blade to a high terminus near the anterior margin. Commissure shows the edge of the shell with an overlapping extension as a sort of flange or lid which effectively seals the interior when the valves are closed. A few specimens with both valves in position demonstrate the tight seal. Both valves are white but are transparent when wet. Some specimens are slightly transparent when dry, especially the protegulum. Measurable dimensions in millimeters are as follows:

Ventral valve (mature), Fig. 1, length 0.40, width 0.50, height 0.20
Ventral valve (old), Fig. 10, length 0.40, width 0.50, height 0.30
Dorsal valve, Fig. 6, length 0.40, width 0.50, height 0.05

Type specimen.—The type specimen is

filed with the U. S. National Museum no. 140110; duplicates are at the University of Kansas Museum.

These specimens are so small and fragile that any attempt to photograph a single type specimen in five positions to show all features would probably result in destruction of the specimen. The several hundred specimens are so nearly alike in morphology and size that it is possible to use several specimens in different positions, any one of which could be called a holotype. On Plate 137, figures 2 and 3 (exterior and interior views) are designated as the holotype.

Remarks.—This species is distinguished by its perfect form and features, well developed foramen, small size, almost hemispherical shape of the ventral valve with a shallow pseudointerarea lacking an intertrough, exterior of the dorsal valve with a well developed protegulum, and interior with a high blade-like median septum beginning near the center of the valve. Both valves have smooth interiors and show no evidence of muscle scars.

This species is unique because of the uniformity in size and shape and the perfection of preservation. The intertrough generally present in the abundant species of the Cambrian Acrotretidae is absent in the Silurian forms. It seems logical to state that the absence of muscle scars, the lack of interior irregularities, and the development of the prominent median septum are evolutionary from the Cambrian forms and diagnostic of the Silurian.

About 500 specimens were mounted and closely examined for size and morphology. Several specimens with both valves together prove that the dorsal and ventral valves found and described belong to the same species. It is estimated that at least 2,000 or more additional specimens remain in the residue samples on hand.

There are too many specimens of the same maximum size to interpret them as other than adults. Many specimens of the protegulum stage of the dorsal valve and a few of the ventral valve were found. A large number of ventral valves have a thick extension below the shell which is never larger than the maximum size and is set off with a sharp break in slope and an indentation. The extension is laminated and represents 10 to 20 growth lines of the gerontic additions to the commissure as the creature progressed into old age. A few of the dorsal valves have gerontic additions. The gerontic growth flange, presence of protegulum stages, uniform-sized specimens, and the geographic distribution with the same size everywhere prove that the shells are chiefly adults and not a nest of embryonic forms that happened to occur at a specific location.

Artiotreta parva superficially resembles *Ceratreta hebes* Bell, but the interiors of both valves are different, especially around the pedicle area, and in the posterior development of the median septum of the dorsal valve. *Scaphelasma* and *Artiotreta* appear to be closely related, with *Artiotreta* representing an evolutionary change from the Middle Ordovician. The dorsal umbo of *Artiotreta* is more inflated and lacks internal thickening around the apex and pedicle opening. Growth lines on the dorsal valve of *Scaphelasma* are ridge-like while *Artiotreta* has uniform laminae.

Horizon and locality.—The collections came from (1) the middle part of Chimney Hill Limestone of Silurian age (Alexandrian), above the glauconite beds, about 300 yards east of U. S. Highway 77, 2 miles north of Springer, Oklahoma, on the south side of the Arbuckle Mountains; (2) Lick Creek at Camp Classen 1½ miles west of U. S. Highway 77 from Cedarvale on the north side of the Arbuckle Mountains; and (3) along U. S. Highway 77 at Cedarville.

Genus ACROTRETELLA Ireland, n. gen.

The shell is subcircular and is thin and fragile. The ventral valve is high and conical in shape, with distinct round foramen at the apex slightly anterior to the posterior face. Fine well-developed growth lines occur around the entire shell. A homeodeltidium is absent. Slightly depressed pseudointerarea is present, with only a slight change in angle of the growth lines that shows the margin of the pseudointerarea. The interior is essentially a reverse of the exterior. The dorsal valve is thin but is thicker than the ventral value and is slightly convex but almost flat. The protegulum is distinct. Growth lines are prominent, forming distinct ridges that become more prominent an-

teriorly. Prominent median septum starts as two small prongs near the center of the valve and merges into a long narrow high spur-like projection near the anterior margin. No muscle scar depressions are apparent, and the interior of the shell is smooth except for the median septum.

Type species.—*Acrotretella siluriana* Ireland, n. sp.

ACROTRETELLA SILURIANA Ireland, n. sp.
Pl. 137, figs. 13–18

The shell is subcircular, is thin and fragile, and is composed of chitinophosphate. It is microscopic in size and is less than 1.00 mm. wide. The ventral valve is high and conical, with distinct round foramen at the apex slightly anterior to the posterior face. Fine well-developed growth lines occur around the entire shell. The homeodeltidium is absent but its existence in a former evolutionary stage is shown by a flattened very slightly depressed pseudointerarea which has growth lines continuous from the rest of the shell with only a slight rounded change in angle of the growth lines to show the margins. Pseudointerarea is broad at the base and converges upward to the foramen at the apex. Foramen is surrounded by three slightly bulbous callouses with none on the anterior side. The interior is smooth and a reverse of the exterior. The dorsal valve is thin but is thicker than the ventral valve and is slightly convex but almost flat. The protegulum is distinct. Growth lines are prominent, forming distinct sharp ridges that become more prominent anteriorly. The number of ridges indicates 10 to 20 periods of growth. The hinge line is well developed but narrow, and is shallow and primitive. Interior of the dorsal valve is marked by a very prominent median septum which starts as two small prongs near the center of the valve and merges into a long narrow high spur-like projection that ends near the anterior margin. No muscle scar depressions are apparent. The interior of the shell is smooth, except for the septum. Commissure is smooth on all specimens available. Measurable dimensions in millimeters are as follows:

Ventral valve, Fig. 13, length 0.64, width 0.74
Ventral valve, Fig. 14, length 0.68, height 0.56
Dorsal valve, Fig. 16, length 0.56, width 0.64
Dorsal valve, Fig. 18, length 0.72, width 0.80

Type specimen.—The type (figs. 13 and 16) is filed with the U. S. National Museum, no. 140111; duplicates are at the University of Kansas Museum.

Remarks.—This form is characterized by its high conical ventral valve with almost total loss of definable homeodeltidium and lack of interior markings. The dorsal valve is nearly flat with a high spur-like median septum most prominent near the anterior margin, which divides into two small prongs near point of attachment close to the center of the shell. It is assumed that the ventral and dorsal valves here described are of the same species. There is little variation of the ventral valve from the type except in size. No second species is definable from the ventral valves found, and it is assumed that the dorsal valves belong to the ventrals which they accompany.

Description of the species is based on eight ventral and sixteen dorsal valves. In comparison to the hundreds of *Artiotreta* found in the samples, the number of *Acrotretella* is small. *Acrotretella* is described as a new form because of the low degree of development of the pseudointerarea, lack of scar depressions on both dorsal and ventral valves, and the single spur-like median septum on the anterior portion of the dorsal valve. *Acrotretella* is separated from *Acrotreta* by the absence of a ventral trough and the presence of the high anterior septum. The ventral valve has some aspects of *Prototreta* Bell (1941), but the trough is absent and the pseudointerarea is a depression and not a plate. The flabellate septum on the dorsal valves of *Prototreta* is absent. The ventral valve of *Acrotreta schmalenseei* Walcott is remarkably similar but differs in the same way as other *Acrotreta* as mentioned above. *Acrotreta idahoensis* Walcott (1912) is twice the size. The apex overhangs the posterior margin, and the dorsal valve has the septum and muscle attachments aggregated posteriorly rather than anteriorly as in *Acrotretella*. *A. idahoensis* also has a well-developed ventral intertrough. *Homotreta interrupta* Bell has a long blade-like septum but not like that of either *Artiotreta* or *Acrotretella*. Also, it has a ventral intertrough and a sulcate dorsal valve which are absent on the specimens of the two new genera. The ventral valve of *Acrotreta*

microscopa Schumard also resembles *Acrotretella siluriana* in shape and exterior markings, but it is twice as large and in some cases an intertrough is present. Also, it is the dorsal septum and its position that distinguishes *Acrotretella*.

Descriptions of the interior markings of valves are lacking in many species, especially for the dorsal valve, and a survey of the descriptions published shows that the markings are concentrated in the posterior portion of the shell. Because the interior markings of *Acrotretella* are concentrated in the anterior half of the dorsal valve, it is considered a new genus separate from all *Acrotreta*. The new genus *Artiotreta* also has dorsal interior markings in the anterior half. Both are thought to be the first known representatives of an unnamed new subfamily.

Broken dorsal valves thought to be *Acrotretella* were found in the residues of Wenlockian limestone from samples collected in the Scutterdin Quarry on the west side of the Woolhope anticline east of Hereford, England.

Horizon and locality.—The collections came from (1) the middle part of Chimney Hill Limestone of Silurian age, above the glauconite beds, about 300 yards east of U. S. Highway 77, 2 miles north of Springer, Oklahoma, on the south side of the Arbuckel Mountains; (2) Lick Creek at Camp Classen 1½ miles west of U. S. Highway 77 from Cedarvale on the north side of the Arbuckle Mountains; and (3) along U. S. Highway 77 at Cedarvale.

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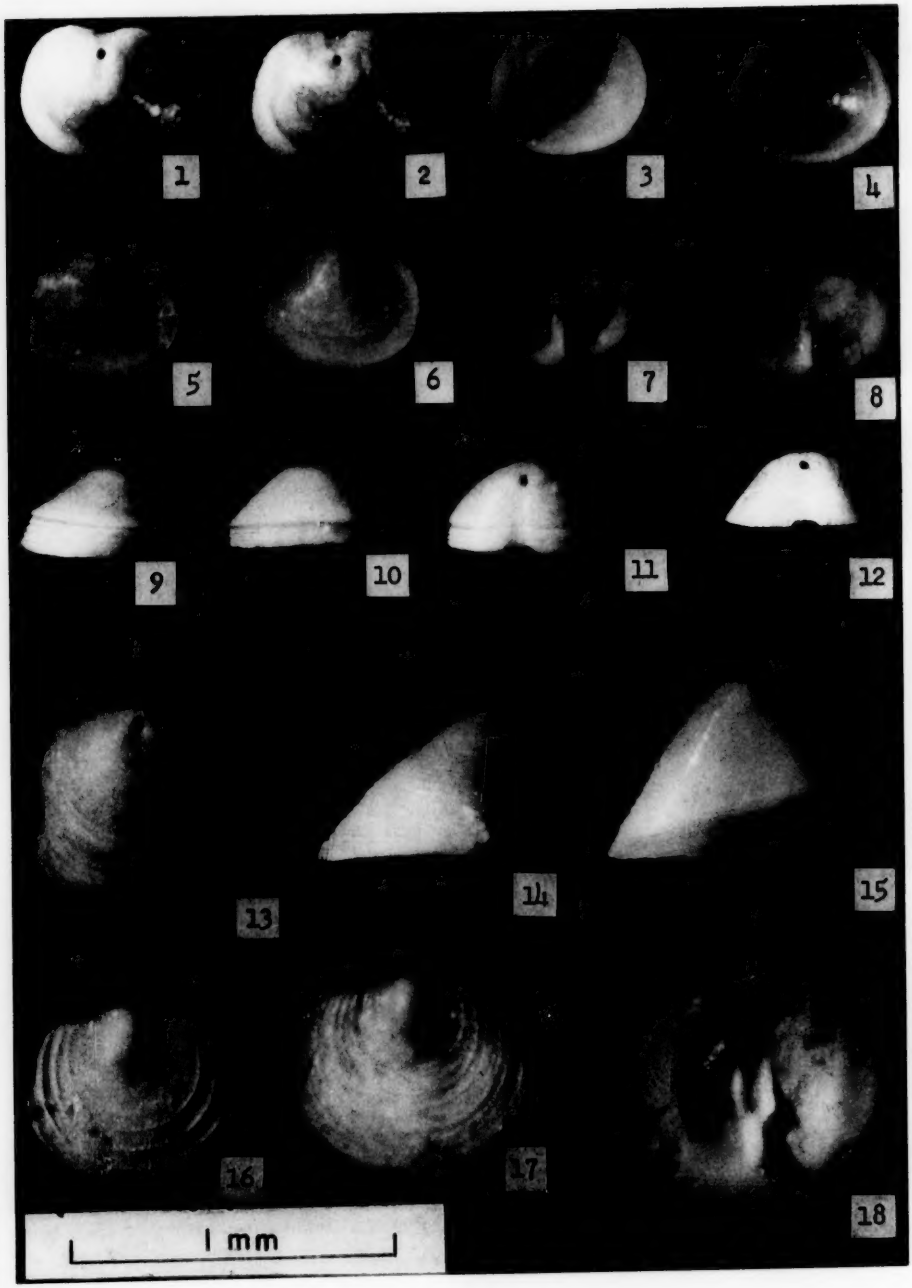
(*Explanation of Plate 137 will be found on page 1142*)

EXPLANATION OF PLATE 137

FIGS. *1–12—Artiotreta parva*, n. sp. ***1,2***, Exteriors of ventral valves, holotype; ***3,4***, interiors of ventral valves, holotype; ***5,6***, exteriors of dorsal valves; ***7,8***, interiors of dorsal valves; ***9***, side view of gerontic ventral valve; ***10***, anterior view of gerontic ventral valve; ***11***, posterior view of gerontic ventral valve; and ***12***, posterior view of a ventral valve.

13–18—Actrotretella siluriana, n. sp. ***13***, Exterior of ventral valve, holotype; ***14***, side view of a ventral valve, paratype; ***15***, posterior view of a ventral valve; ***16,17***, exteriors of dorsal valves; ***17***, paratype; and ***18***, interior of dorsal valve, paratype.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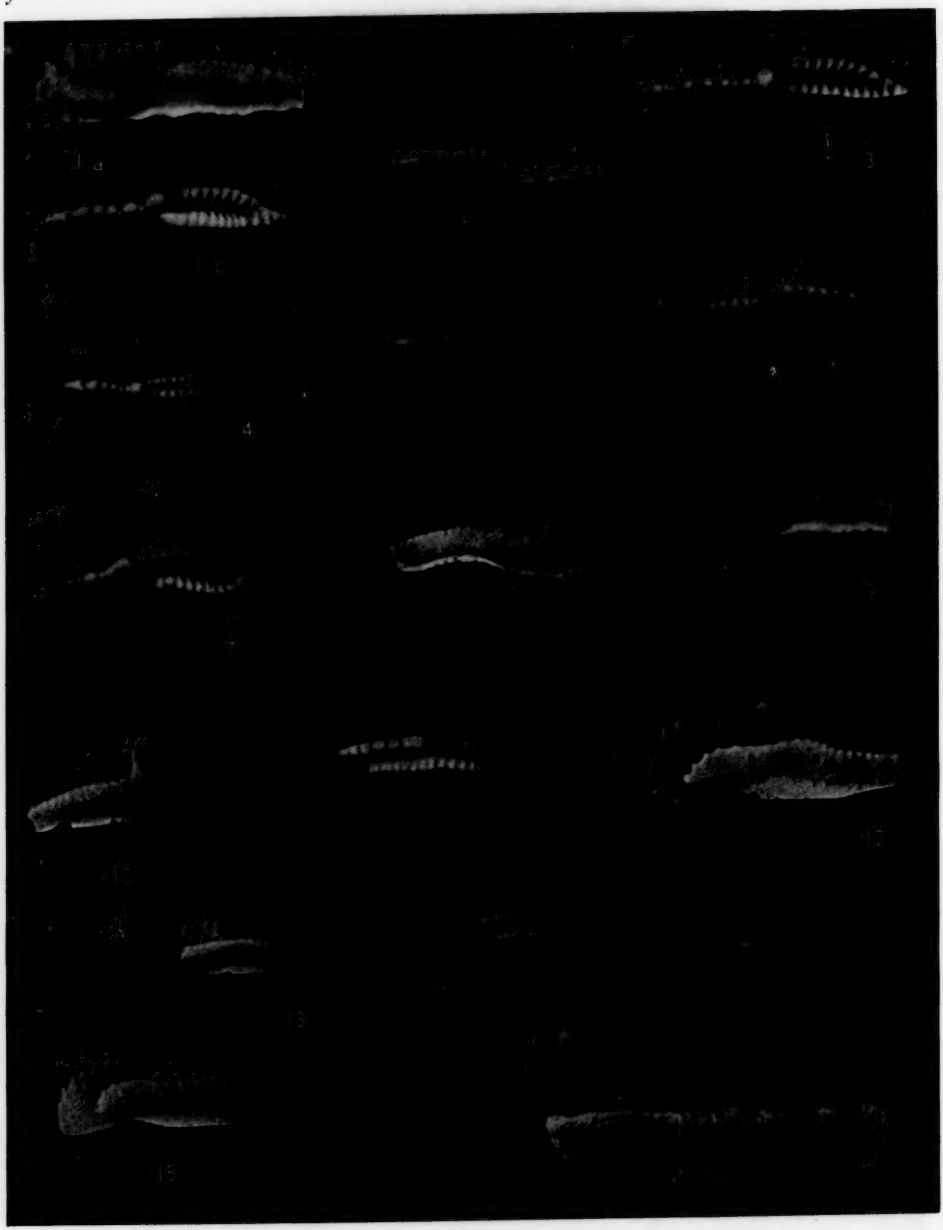

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CONODONTS FROM THE KINKAID FORMATION (CHESTER) IN ILLINOIS

CARL B. REXROAD AND ROBERT C. BURTON
Illinois State Geological Survey, Urbana, and
West Texas State College, Canyon

ABSTRACT—The Kinkaid Formation is the uppermost formation in the standard section of the Chester Series for the Mississippian System in North America. The type section of the formation and two additional long sections in southern Illinois were chosen for study to show the nature of the youngest Chester conodonts of the area and to determine vertical variations in the fauna. The formation is divisible into four lithologic units, here referred to in ascending order as A, B, C, and D.

The fauna of the lower three lithologic units is typically Chester in aspect but is definitive of the Kinkaid. Genera present are *Cavusgnathus, Cladognathodus, Elsonella?, Falcodus?, Gnathodus, Hibbardella, Hindeodella, Lambdagnathus, Ligonodina, Neoprioniodus, Ozarkodina,* and *Spathognathodus.* Some elements in unit C are interpreted as migrants, and these serve to distinguish the unit. Unit B differs from the other two units in the sparsity of conodonts found in it.

The fauna of unit D is strikingly different from that of the lower three units and includes the additional genus *Streptognathodus* which comprises over one-third of the fauna. *Cladognathodus, Elsonella?, Gnathodus,* and *Lambdagnathus* were not found in unit D. Other differences between the lower three units and unit D are related to differences in species and relative abundances of species. The unit D conodonts have affinities with both the Mississippian and the Pennsylvanian, and its stratigraphic placement must remain an open question.

As an adjunct to the stratigraphic studies, the new species *Streptognathodus unicornis* and *Falcodus? alatoides* are named.

INTRODUCTION

PURPOSE AND SCOPE

PREVIOUS studies of conodonts from the Chester Series in the Illinois Basin (Cooper, 1947; Rexroad 1957, 1958) have demonstrated that conodonts will be a useful tool in stratigraphic investigations of Chester strata. Accordingly, additional detailed studies are being undertaken in order to expand our knowledge of the conodont faunas from the North American standard reference sections for the Chester Series.

It was hoped that the study of the conodonts of the Kinkaid Formation, the uppermost unit of the standard sequence, would show the nature of the youngest Chester conodonts of the area and would also provide additional evidence concerning the age relationships of the uppermost beds, which are faunally atypical of the Kinkaid (Swann, personal communication). The type section of the Kinkaid Formation and two sections where the uppermost beds are exposed were chosen for sampling. The locations were spaced so the collections would show any

EXPLANATION OF PLATE 138

Numbers in parentheses after explanations refer to locality and sample numbers; for example, (2–8) refers to locality 2, sample 8. All figures are magnified ×40.

FIGS. *1–9—Streptognathodus unicornis* Rexroad & Burton, n. sp. *1a,1b,* Inner lateral and oral views of holotype (2–8); *2–6,9,* all paratypes, aboral, oral, oral, aboral, oral, and inner lateral views respectively (2–7, 2–12, 2–7, 2–7, 2–12, 2–8); and *7,8,* oral and outer lateral views of specimens transitional from *Cavusgnathus unicornis* Youngquist & Miller (both 2–12).

10–12—Cavusgnathus unicornis Youngquist & Miller. Outer lateral, oral, and inner lateral views (1–4 to 6, 1–1 to 3, 1–4 to 6 composite samples).

13,15—Cavusgnathus regularis Youngquist & Miller. Inner lateral views (1–4 to 6 composite, 3–5).

14—Cavusgnathus convexa Rexroad. Inner lateral and outer views of young specimen (1–26).

16—Cavusgnathus cristata Branson & Mehl. Inner lateral view (1–31).

variations in the geographic pattern of conodont distribution.

ACKNOWLEDGMENTS

Charles Collinson directed the study and gave generously of his time and energies in all phases of the study. D. H. Swann selected the sections to be studied and his discussion of the stratigraphic problems was an important contribution. Both gave valuable criticism of the manuscript, as did H. B. Willman, A. J. Scott, and Romayne Skartvedt. Robert Townsend and R. I. Pinney helped collect and process samples. Text-figures were prepared by Marie Litterer. All are with the Illinois State Geological Survey.

The late W. H. Hass of the U. S. National Museum verified identification of six specimens from the Renault and Barnett Formations as *Neoprioniodus singularis* and was most helpful on several general problems. The University of Houston and Texas Technological College made available laboratory facilities for the processing of samples.

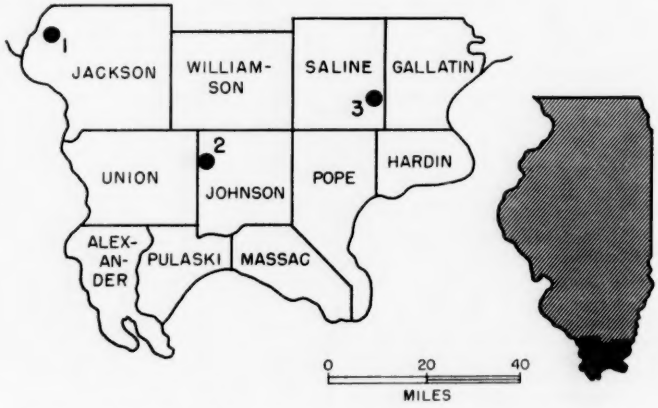
STRATIGRAPHIC SUMMARY

The Kinkaid Formation was named by Stuart Weller (1920) for exposures on Kinkaid Creek, Jackson County, Illinois. The type locality (locality 1 of this study) is near the northwestern end of the outcrop belt which forms an arc around the southwestern, southern, and southeastern margin of the Illinois Basin. The Kinkaid is the uppermost formation of the standard Chester section, conformably overlying the Degonia Sandstone. The Kinkaid is in turn unconformably overlain by strata of Pennsylvanian age.

The geographic positions of the localities studied are shown in Text-figure 1. The lithologic sequence of each section studied is detailed in Text-figures 2,3, and 4, along with the position of productive and barren samples.

The thickness of the formation varies greatly, primarily because of pre-Pennsylvanian erosion, and only part of the formation is represented at the type locality. Where fully developed, the Kinkaid Formation is divisible into four units which, for the purpose of this paper, are designated in ascending order A, B, C, and D.

Unit A at the base of the formation is typically a medium to massively bedded highly fossiliferous limestone about 25 to 30 feet thick. This is the part of the Kinkaid represented in Indiana by the Negli Creek Limestone. Unit B is about 100 feet thick and is composed mostly of shale, although a number of poorly fossiliferous silty limestones are present, particularly in the



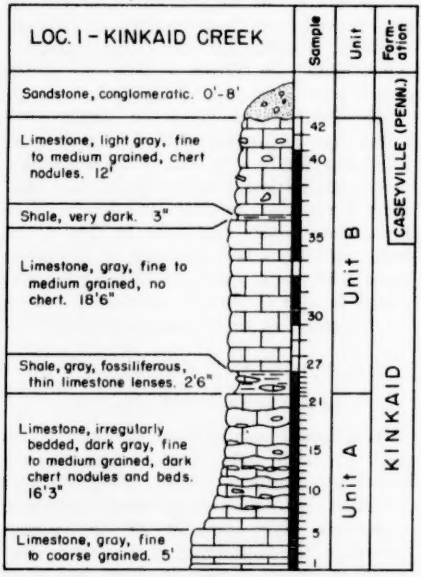
TEXT-FIG. 1—Localities from which conodonts were collected. Outcrop diagrams (Text-figs. 2–4) show detailed descriptions of sections.

middle part of the unit. The limestones are dolomitic in some places. Unit C is another fossiliferous medium to massively bedded limestone about 25 feet thick. Uppermost Kinkaid, unit D, is dominantly a shale, but it also contains some thin argillaceous and fossiliferous limestones.

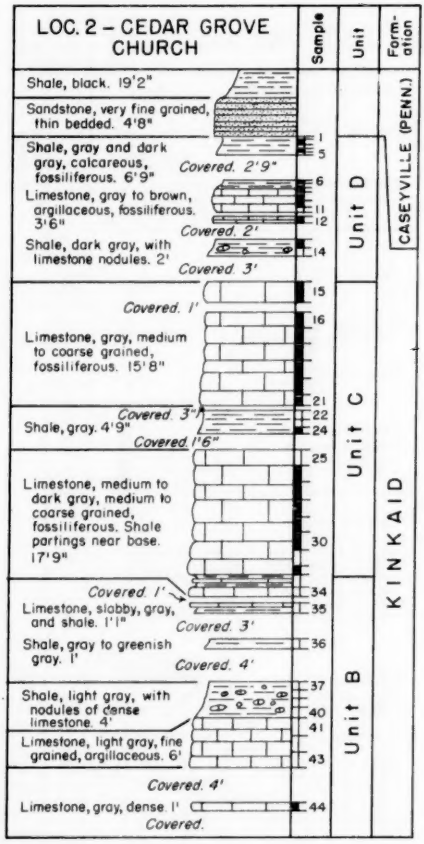
Unit A and approximately the lower half of unit B are represented at the type section (locality 1). The latter section is not lithologically characteristic because of lateral gradation from the typical shale into the silty poorly fossiliferous limestone exposed in the upper part of the quarry. Locality 2 is a representative section of the upper half to two-thirds of unit B, all of unit C, and approximately 16 feet of unit D. Except for covered intervals, locality 3 shows an almost complete section of the Kinkaid.

THE CONODONT FAUNA

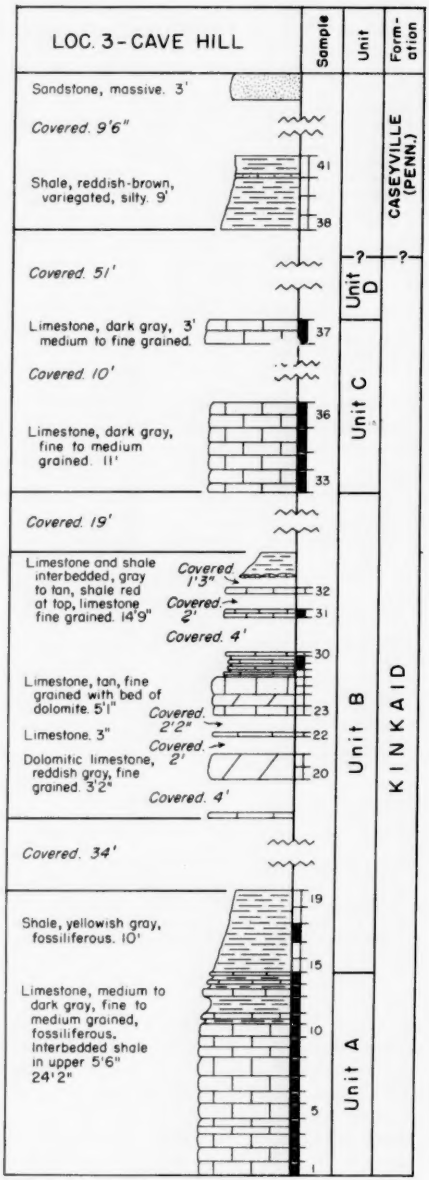
Twenty-eight named species, referable to twelve genera, were identified from the Kinkaid Formation. In addition, an unnamed species of *Hindeodella* is abundant. *Cavusgnathus*, *Ligonodina*, *Neoprioniodus*, *Hindeodella*, and *Streptognathodus* were reported by Cooper (1947) from the uppermost Kinkaid of the Cedar Grove Church section (Text-fig. 3). In addition to the first four of these, Rexroad (1957) recorded representatives of *Hibbardella*, *Cladognathodus*, *Lambdagnathus*, *Ozarkodina*, *Spathogna-*



TEXT-FIG. 2—Kinkaid Creek, locality 1. MacRow, J. R. Giffin, or Cromwell quarry on north bank of Kinkaid Creek, SE¼ NW¼ NW¼ sec. 6, T. 8 S., R. 4 W., Campbell Hill quadrangle, Jackson County, Illinois.



TEXT-FIG. 3—Cedar Grove Church, locality 2. Section in gully west of road up bluff from Cedar Grove Church, NE¼ NW¼ sec. 31, T. 11 S., R. 2 E., Carbondale quadrangle, Johnson County, Illinois. (Modified after Lamar, 1925, p. 80).



TEXT-FIG. 4—Cave Hill, locality 3. Section in abandoned quarry, along road, and on hillside, on western flank of Cave Hill, SW¼ NW¼ sec. 3, T. 10 S., R. 7 E., Equality quadrangle, Saline County, Illinois.

thodus, and *Elsonella?* from the shale unit of the type Kinkaid section. All have been recognized in this study, as have species of *Gnathodus* and *Falcodus?*. Of the twenty-eight named species, *Streptognathodus unicornis* and *Falcodus? alatoides* are new. Incompletely known varieties of *Hibbardella milleri* and *Neoprioniodus varians* are described.

The stratigraphic and geographic distribution of the Kinkaid conodonts is shown in Table 1. The percentage distribution of the genera in each of the four lithologic units of the formation is presented in Table 2. Table 3 gives the same information for the species. Tables 2 and 3 are based on the initial set of samples which yielded slightly more than 2,000 generically identifiable specimens and over 1,400 specifically identifiable individuals when all conodonts were picked. Approximately 1,800 additional specimens from subsequent bulk samples were used just to substantiate the absence of species. Only the less common species and better specimens of the common species were picked from these samples on the first attempt. Nonetheless, the general proportions from the latter correspond quite closely to the percentages shown in Table 2.

The information given on Tables 1–3 shows that the fauna of the lower three units compares closely with that of the remainder of the underlying Chester Series but that there is a marked vertical variation between these lower units and unit D. There are lesser variations between each of the lower units with some evidence of migrant elements in unit C. Details of these elements are discussed in the following section.

ZONATION AND CORRELATION

LOWER FAUNA, UNITS A, B AND C

The faunal compositions of units A, B, and C, with only two exceptions, are strikingly uniform. First, *Neoprioniodus singularis* is found only in unit C and there comprises eight percent of the fauna. Secondly, the abundance of *Gnathodus commutatus* increases sharply from less than

TABLE 1—OCCURRENCE OF CONODONT SPECIES

LOCALITY NUMBERS REFER TO OUTCROPS SHOWN IN TEXT-FIGURE 1 AND DESCRIBED IN DETAIL BY TEXT-FIGURES 2–4. A, B, C, AND D REFER TO INFORMAL STRATIGRAPHIC SUBDIVISIONS OF THE KINKAID FORMATION

Locality	1A	1B	2B	2C	2D	3A	3B	3C
Cavusgnathus	×	×	×	×	×	×	×	×
C. convexa	×	×	–	×	×	×	–	–
C. cristata	–	×	–	–	–	–	–	–
C. navicula	×	×	–	×	×	×	×	×
C. regularis	×	×	–	×	–	×	–	×
C. unicornis	×	×	×	×	×	×	–	×
Cladognathodus	×	×	–	×	–	×	–	–
C. prima	×	×	–	×	–	×	–	–
Elsonella?	×	×	–	×	–	×	×	–
E.? imperfecta	×	×	–	×	–	×	×	–
Falcodus?	×	×	–	×	×	×	–	–
F.? alatoides	×	×	–	×	–	×	–	–
Gnathodus	×	–	–	×	–	×	–	×
G. commutatus	×	–	–	×	–	×	–	×
Hibbardella	×	×	–	×	×	×	×	×
H. fragilis	×	×	–	–	–	×	–	–
H. milleri	×	×	–	×	×	×	–	×
H. ortha	×	×	–	×	×	×	×	×
Lambdagnathus	×	×	–	×	–	×	–	×
L. fragilidens	×	–	–	×	–	×	–	–
Ligonodina	×	×	–	×	×	×	×	×
L. hamata	×	×	–	×	×	×	×	×
L. levis	×	×	–	×	–	×	–	×
L. n. sp.	×	–	–	×	×	×	–	×
Neoprioniodus	×	×	–	×	×	×	×	×
N. camurus	×	×	–	×	×	×	–	×
N. loxus	×	×	–	×	×	×	–	–
N. scitulus	×	×	–	×	×	×	×	×
N. singularis	–	–	–	×	–	–	–	×
N. varians	×	×	–	×	×	×	×	×
Ozarkodina	×	×	–	×	×	×	–	×
O. compressa	×	×	–	×	×	×	–	×
O. curvata	×	×	–	×	×	×	–	–
O. delicatula	×	–	–	–	×	×	–	–
Spathognathodus	×	×	–	×	×	×	×	×
S. campbelli	–	×	–	–	×	–	–	–
S. cristula	×	×	–	×	×	×	×	×
S. minutus	–	–	–	–	×	–	–	–
Streptognathodus	–	–	–	–	×	–	–	–
S. unicornis	–	–	–	–	×	–	–	–

one percent in units A and B to 20 percent in unit C. Both serve to set unit C apart from the lower units.

The limitation of *Neoprioniodus singularis* and *Gnathodus commutatus* to units A, B and C is not due to stratigraphic range, because both species have been found as low as the Renault Formation in the Illinois Basin.

TABLE 2—VERTICAL DISTRIBUTION OF GENERA WITHIN THE KINKAID FORMATION BY PERCENT

Genus \ Unit	A	B	C	D
Cavusgnathus	31.2	46.2	30.2	7.3
Cladognathodus	2.1	1.2	1.1	0
Elsonella?	0.3	0.8	0.3	0
Falcodus?	1.8	0.4	0.6	0.5
Gnathodus	0.5	0	13.9	0
Hibbardella	4.8	2.2	2.2	2.0
Lambdagnathus	1.6	0.2	1.4	0
Ligonodina	16.0	9.1	10.3	15.1
Neoprioniodus	24.5	23.1	26.7	30.3
Ozarkodina	5.1	4.5	5.0	7.8
Spathognathodus	12.3	12.2	8.7	2.9
Streptognathodus	0	0	0	34.1
	100.2	99.9	100.4	100.0

Additionally, both have been figured from the Dimple Limestone (lower Pennsylvanian) of Texas (Ellison & Graves, 1941): *N. singularis* as *Prioniodus barbatus* Branson & Mehl and *G. commutatus* as *Spathognathodus commutatus* Branson & Mehl. It is possible, of course, that these specimens represent reworked Mississippian material.

In the Glen Dean Formation in the Illinois Basin there is strong evidence of a southern faunal province at the margin of the basin which reflects a faunal assemblage closely similar to that of the upper part of the Barnett Formation of Texas and the Caney Shale of Oklahoma (Rexroad, 1958). Because *Neoprioniodus singularis* and *Gnathodus commutatus* are typical of the Texas and Oklahoma formations, it is suggested that there was migration and intermingling of a southern faunal assemblage with the Illinois Basin population during the deposition of unit C.

With the exception of these two species, both the generic and specific composition of the three lower units is remarkably uniform. There is another difference between the units, however, and that is the marked sparsity of conodonts in unit B. The exception is at locality 1, which is lithologically atypical of unit B and appears likewise to be atypical in the numbers of conodonts present. Thus, the three lower units are apparently distinctive to the extent that unit B is generally sparingly fossiliferous in contrast to units A and C, and unit C contains abundant specimens of *Gnathodus commutatus* and *Neoprioniodus singularis* which are rare or absent in the other two units.

UPPER FAUNA, UNIT D

The contrast between the conodonts of units A, B, and C and those of unit D is striking. At the generic level *Streptognathodus* comprises over one-third of the unit D fauna. This increase is largely balanced by a marked decrease in *Cavusgnathus*. The transitional forms between the two show that *Cavusgnathus* is ancestral to *Streptognathodus*, so that the change in the proportions of these two genera represents an evolutionary trend rather than a migratory influx.

The generic difference between the lower three units and unit D is further emphasized by the fact that four genera of the lower units are not present in unit D. These are *Cladognathodus, Elsonella?, Gnathodus,* and *Lambdagnathus. Lambdagnathus* has not been recognized below the Chester nor has *Cladognathodus* been recognized below the Glen Dean Formation (upper middle Chester). Unit C apparently is the top limit of their range.

Analyses of species differences between the four units substantiate the recognition of unit D as a distinctive unit. Seven species present in all three lower units are not found in unit D. These are *Cavusgnathus convexa, C. unicornis, C. regularis, Cladognathodus prima, Elsonella? imperfecta, Hibbardella milleri,* and *Ligonodina levis.* Six species found in at least one of the lower units are not found in unit D.

Conversely, two species, *Spathognathodus minutus* and *Streptognathodus unicornis,* which are present in unit D are not present in the lower units. *S. minutus* previously has been recognized only from Pennsylvanian beds. This apparently is the point at which *S. minutus* develops from *Spathognathodus cristula.* Although both are present in unit D, *S. cristula* drops from percentages of 15%, 15%, and 10% in units A, B, and C, respectively, to less than one percent in unit D.

Several other species show marked change in importance between the lower and upper faunal units. *Ligonodina hamata* shows a sharp decrease from the lower into the up-

TABLE 3—VERTICAL DISTRIBUTION OF SPECIES WITHIN THE KINKAID FORMATION BY PERCENT

Species \ Unit	A	B	C	D
Cavusgnathus convexa	1.2	3.2	x	0
C. cristata	0	0.3	0	0
C. unicornis	9.6	20.6	5.6	0
C. navicula	6.4	8.7	16.0	4.6
C. regularis	5.6	8.7	1.2	0
Cladognathodus prima	1.1	1.2	0.4	0
Elsonella? imperfecta	0.5	1.2	x	0
Falcodus? alatoides	1.1	0.3	0.4	0
Gnathodus commutatus	0.8	0	20.0	0
Hibbardella fragilis	1.1	0.6	0	0
H. milleri	4.5	1.4	2.0	1.3
H. ortha	1.1	0.6	0.4	1.3
Lambdagnathus fragilidens	0.2	0	0.8	0
Ligonodina hamata	10.8	8.1	8.0	1.3
L. levis	4.8	2.3	2.0	0
L. n. sp.?	0.8	0	0.8	11.1
Neoprioniodus camurus	2.5	2.3	1.2	x
N. loxus	2.6	0.9	1.6	0.7
N. scitulus	24.3	18.6	15.6	36.6
N. singularis	0	0	8.0	0
N. varians	1.9	1.4	2.0	0.7
Ozarkodina compressa	0.8	0.9	2.4	1.3
O. curvata	3.1	1.4	0.8	0.7
O. delicatula	0.3	0	0	x
Spathognathodus campbelli	0	1.2	0	1.3
S. cristula	15.2	15.9	10.4	0.7
S. minutus	0	0	0	x
Streptognathodus unicornis	0	0	0	37.9
	100.3	99.8	99.6	99.5

x—Found only in bulk samples.

per unit, while this is reversed by the variant form, *L.* n. sp.?, which increases sharply in unit D. *Cavusgnathus navicula* increases to a maximum of 16 percent in unit C, then drops to five percent in unit D.

It is apparent that unit D contains a conodont fauna which readily distinguishes it from units A, B, and C. It is lithologically distinct as well. Accordingly, we recommended that this unit be recognized by application of formal stratigraphic nomenclature.

STRATIGRAPHIC IMPLICATION

The lower faunal unit is typical of the Chester in aspect, but it is distinct. Twenty-three of the 26 species from this unit have been recorded previously from underlying Chester formations. Of those that have not, *Cavusgnathus navicula* gives promise of being an excellent guide to the Kinkaid Formation. It is an important element in this formation but has not been identified in a restudy of Clore and Menard collections.

Ligonodina n. sp.? is a minor element in the lower faunal unit but adds to the distinctiveness of the Kinkaid fauna, as does the *Hibbardella milleri* variant which is known only from the Kinkaid. It seems likely that *Ozarkodina delicatula*, previously reported only from the Pennsylvanian and a minor element in the Kinkaid, will be recognized lower in the section.

Spathognathodus spiculus is particularly abundant in the lower part of the Chester Series, and it continues through the Clore. Thus, the Kinkaid is the only Chester formation lacking this species. Ranges of several other Chester species with apparently limited ranges are not as well established, but the present study helps to define their ranges. Similarly, this study has shown that ranges of several species are to be extended within the Illinois Basin. These species include *Hibbardella ortha*, *Lambdagnathus fragilidens*, *Ligonodina levis*, *Ozarkodina curvata* and *Gnathodus commutatus*, previously unrecorded above the Glen Dean Formation; *Neoprioniodus loxus*, previously unrecorded above the Menard; and *Neoprioniodus varians*, previously unrecorded above the Clore.

The conodont fauna of unit D differs markedly from pre-Kinkaid Chester conodonts as well as from the lower faunal unit of the Kinkaid. The answer as to whether its affinities are closer to the Kinkaid beds or to the overlying Pennsylvanian must wait for additional detailed studies of the lower Pennsylvanian conodonts. Seven of the eight genera present in unit D continue into the Pennsylvanian, whereas three genera from the lower Kinkaid units fail to carry into unit D.

Another approach to this problem may be found in relating the North American standard sequence with that of Europe by means of intermediate sections containing both conodonts and goniatites. The Kinkaid Formation and unit D encompass a more limited portion of Chester time than do the Caney Shale of Oklahoma and the Barnett Formation of Texas. However, the recognition of *Streptognathodus* and the two distinct zones in the Kinkaid Formation of the Illinois Basin gives a point for relatively precise correlation. Elias (1956) states that "the age of the Sand Branch [Member of the Caney Shale] is determined by its goniatite *Eumorphoceras*, an exclusive and most characteristic genus of the lower Namurian of Europe; and this conclusion, in turn, assigns the Sand Branch to Chester age." The lower part of the Sand Branch Member contains *E. girtyi* Elias and is correlated by Elias with the E_1 zone of the Namurian and the upper part of the Sand Branch containing *E. bisulcatum, s. s.*, with the E_2 zone. However, the fossils are described as coming from lentils and the conodont-bearing lentil of the upper part of the Sand Branch is about 40 feet higher in the section than the *E. bisulcatum*-bearing lentil. *Streptognathodus*, therefore, comes from a zone which could be sufficiently younger than the underlying beds to be above the range of the E_2 zone.

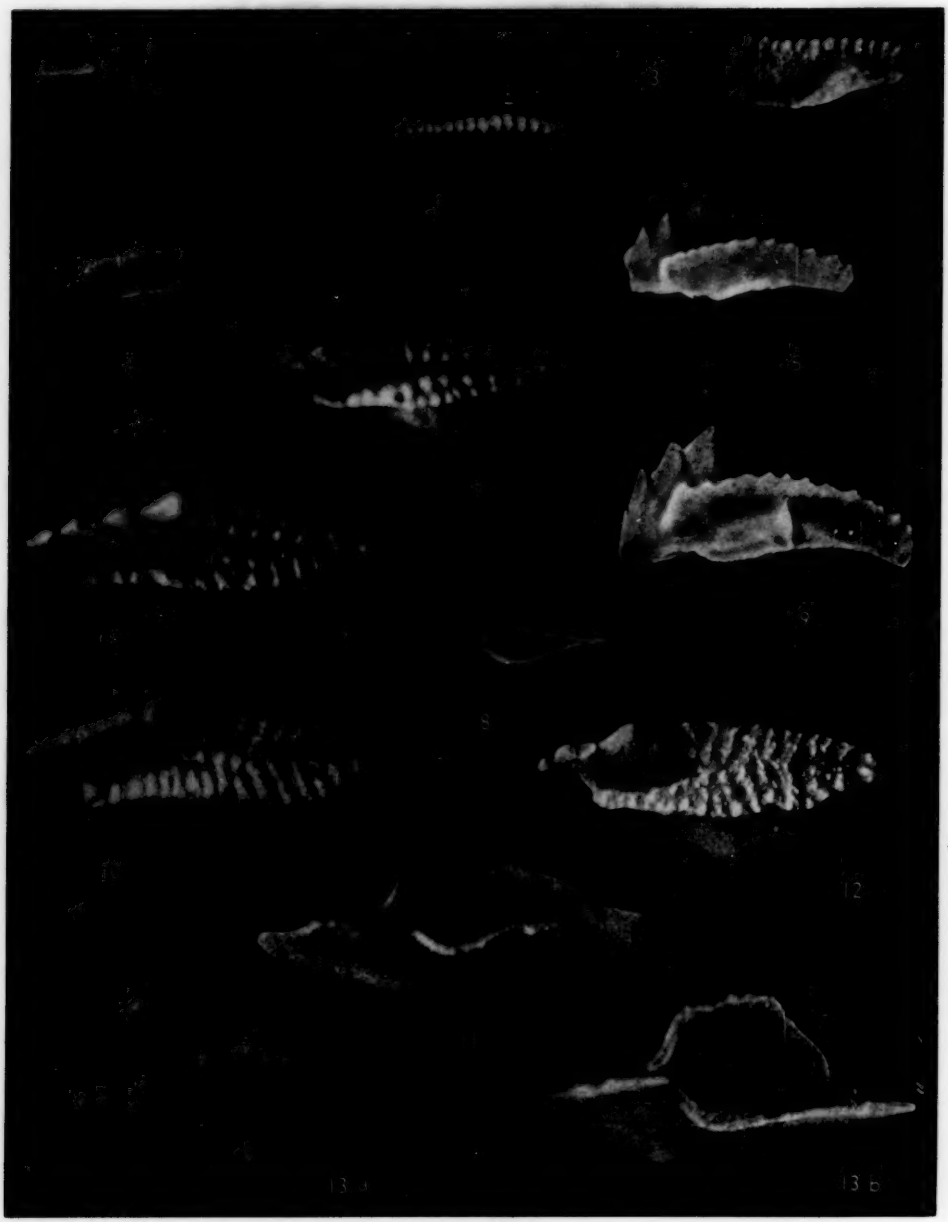
Miller & Youngquist (1948) record *Eumorphoceras bisulcatum* and *E. plummeri* from several Barnett locations. *Streptognathodus* has not been recorded from these same units, so again there is the possibility that the Barnett occurrences of *Streptognathodus* are above the E_2 zone (Defandorf, 1960). It should be added that Elias (1956) refers *E. bisulcatum* to *E. girtyi* and introduces the subgenus *Edmooroceras* for *Eumorphoceras plummeri*.

EXPLANATION OF PLATE 139

Numbers in parentheses after explanations refer to locality and sample numbers; for example, (2–20) refers to locality 2, sample 20. All figures are magnified ×40.

FIGS. *1–3*—*Gnathodus commutatus* (Branson & Mehl). *1,3*, Inner and outer lateral views of a mature specimen (2–20); and *2*, oral view (2–32).

4–13—*Cavusgnathus navicula* (Hinde). *4,5,8*, Inner lateral, inner lateral, and aboral views of young specimens (2–32, 2–21, 1–4 to 6 composite); *6*, oral view (2–32); *7*, oral view (2–32); *9*, inner lateral view (2–32); *10*, oral view (1–1 to 3 composite); *11*, aboral view (2–32); *12*, oral view (1–36); and *13a,b*, inner lateral and aboral views (3–3).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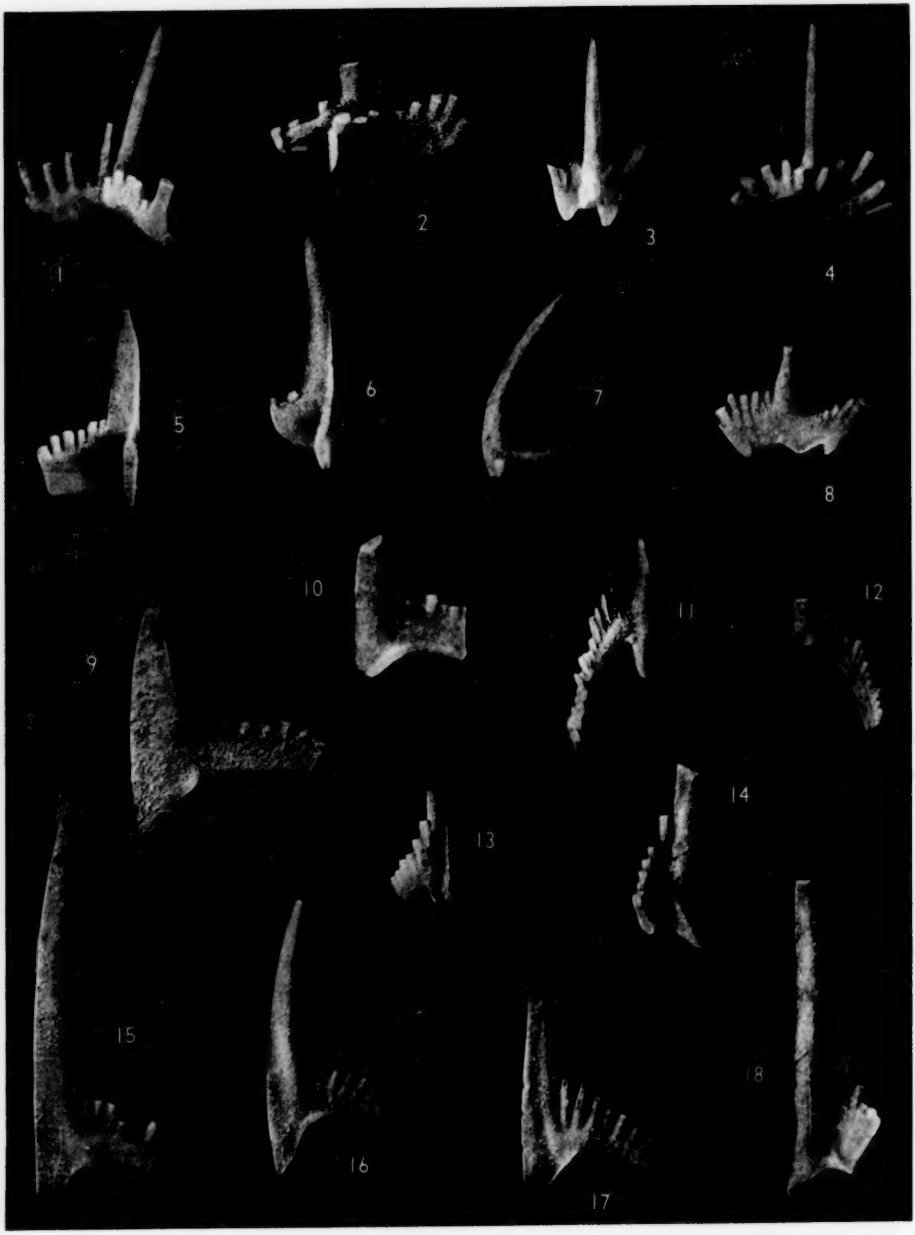
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Additional faunal studies will be necessary before the Mississippian versus Pennsylvanian affinites of unit D can be established.

SYSTEMATIC PALEONTOLOGY

The type and figured specimens described and illustrated in this paper have been reposited at the Illinois State Geological Survey. Under the subheading *Distribution* in the discussion of each species, the formations in which it occurs are listed. For detailed information about stratigraphic and geographic distribution in southern Illinois see Tables 1, 2, and 3.

Genus CAVUSGNATHUS Harris & Hollingsworth

Type species: *Cavusgnathus alta* Harris & Hollingsworth

CAVUSGNATHUS CONVEXA Rexroad

Pl. 138, fig. 14

Cavusgnathus convexa REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 17, pl. 1, figs. 3–6; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 16, pl. 1, figs. 12–14.

Material studied.—28 specimens from this study.

Repository.—Illinois State Geological Survey, 15P49 (figured specimen).

CAVUSGNATHUS CRISTATA Branson & Mehl

Pl. 138, fig. 16

Cavusgnathus cristata BRANSON & MEHL, 1940, Denison Univ. Bull., Jour. Sci. Labs, v. XXXV, p. 177, pl. V, figs. 26–31; Hass, 1953, U. S. Geol. Survey, Prov. Paper 243-F, p. 77, pl. 14, figs. 12–14; ELIAS, 1956, Petroleum Geology of southern Oklahoma: Am. Assoc. Petroleum Geologists, v. 1, p. 115, pl. II, figs. 1–6; REXROAD, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 16, pl. 1, figs. 15–17.

Cavusgnathus cristata var. *grandis* ELIAS, 1956, Petroleum Geology of southern Oklahoma: Am. Assoc. Petroleum Geologists, v. 1, p. 115, pl. II, figs. 12–14.

Material studied.—One specimen from this study.

Repository.—Illinois State Geological Survey, 15P4 (figured specimen).

CAVUSGNATHUS NAVICULA (Hinde)

Pl. 139, figs. 4–13

Polygnathus navicula HINDE, 1900, Nat. Hist. Soc. Glasgow, Trans., v. 5, n.s., pt. 3, p. 342, pl. IX, fig. 5; HOLMES, 1928, Proc. U. S. Natl. Mus., v. 72, art. 5, p. 18, pl. 7, fig. 14.

Cavusgnathus cristata Branson & Mehl, COOPER, 1947, Jour. Paleontology, v. 21, p. 91, pl. 20, figs. 4–10; BISCHOFF, 1957, Hess. Landesamt. Bodenf., Abhl., Hf. 19, p. 19, pl. 2, figs. 7a,b.

Cavusgnathus navicula (Hinde), CLARKE, 1960, Edinburgh Geol. Soc., Trans., v. 18, pt. 1, p. 23, pl. IV, figs. 1–3.

Cavusgnathus inflexa CLARKE, 1960, Edinburgh Geol. Soc., Trans., v. 18, pt. 1, p. 23, pl. III, figs. 17,19.

In ontogenetic development the trough is of moderate depth in juvenile specimens, becomes shallow in adults, and commonly is filled-in except at the extreme anterior end in gerontic individuals. On each parapet there is a change from a single row of nodes to a double row, and in some individuals the nodes unite to form subparallel transverse ridges which may extend irregularly across the filled-in trough of the gerontic stage. *Cavusgnathus inflexa* Clarke reflects one

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EXPLANATION OF PLATE 140

Numbers in parentheses after explanations refer to locality and sample numbers; for example, (3–5) refers to locality 3, sample 5. All figures are magnified ×40.

FIGS. *1,2*—*Cladognathodus prima* (Rexroad). Inner lateral views (1–4 to 6 composite, 3–5).
3,4—*Hibbardella milleri* Rexroad. *3*, Posterior view of variant (2–12); *4*, anterior view of typical mature specimen (1–21).
5,6—*Hibbardella ortha* Rexroad. Inner lateral views (1–4 to 6 composite, 2–21).
7—*Hibbardella fragilis* (Rexroad). Lateral view (1–4 to 6 composite).
8—*Falcodus? alatoides* Rexroad & Burton, n. sp. Inner lateral view of holotype (1–3).
9,10—*Neoprioniodus varians* (Branson & Mehl). *9*, Inner lateral view of a variant (3–4); and *10*, inner lateral view (2–32).
11—*Neoprioniodus camurus* Rexroad. Inner lateral view (1–4 to 6 composite).
12—*Neoprioniodus loxus* Rexroad. Inner lateral view (3–5).
13,14,18—*Neoprioniodus singularis* (Hass). Outer, inner, and inner lateral views (2–27, 3–11, 2–32).
15–17—*Neoprioniodus scitulus* (Branson & Mehl). Inner lateral views (3–5, 2–32, 2–32).

stage of this development and accordingly is placed in synonomy.

From a study of the Kinkaid specimens alone the impression is given that *Cavusgnathus navicula* developed from *C. unicornis* Youngquist & Miller, both because of the stratigraphic relations and because the early juvenile specimen of *C. navicula* are so closely similar to *C. unicornis*. However, the stratigraphic relations differ in the Scottish Carboniferous Limestone, and this question must remain unsettled. The filling of the median trough in gerontic individuals results in a form similar to the genus *Polygnathodella*. It is likely that this development in *C. navicula* or a similar species provides a transition from *Cavusgnathus* to *Polygnathodella*, a Pennsylvanian form.

Material studied.—183 specimens.

Repository.—Illinois State Geological Survey, 15P3, 15P4 to 15P60, 15P92, 15P93 (figured specimens).

CAVUSGNATHUS REGULARIS Youngquist & Miller
Pl. 138, figs. 13,15

Cavusgnathus regularis YOUNGQUIST & MILLER, 1949, Jour. Paleontology, v. 23, p. 619, pl. 101, figs. 24,25.

Material studied.—130 specimens from this study.

Repository.—Illinois State Geological Survey, 15P2, 15P50 (figured specimens).

CAVUSGNATHUS UNICORNIS Youngquist & Miller
Pl. 138, figs. 10–12

Cavusgnathus unicornis YOUNGQUIST & MILLER, 1949, Jour. Paleontology, v. 23, p. 619, pl. 101, figs. 18–23; REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 17, pl. 1, fig. 7; LYS & SERRE, 1957, Inst. Franç. Pétrole, Rev., v. XII, no. 10, p. 1042, pl. II, figs. 3a,3b; REXROAD, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 17, pl. 1, figs. 6–11.

Material studied.—205 specimens from this study.

Repository.—Illinois State Geological Survey, 15P51, 15P52, 15P53 (figured specimens).

Genus CLADOGNATHODUS Rexroad
(CLADOGNATHUS Rexroad)
Type species: *Cladognathus prima* Rexroad
CLADOGNATHODUS PRIMA (Rexroad)
Pl. 140, figs. 1,2

Cladognathus prima REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 28, pl. 1, figs. 8–10.

Kladognathus prima REXROAD, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 19, pl. 3, fig. 6.

Material studied.—30 specimens from this study.

Repository.—Illinois State Geological Survey, 15P15, 15P61 (figured specimens).

Genus ELSONELLA Youngquist
Type species: *Elsonella prima* Youngquist
ELSONELLA? IMPERFECTA (Rexroad)
Pl. 141, fig. 1

Trichonodella imperfecta REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 41, pl. 4, figs. 4,5; —, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 26, pl. 4, fig. 6.

Elsonella? imperfecta REXROAD & COLLINSON, 1961, Illinois Geol. Survey, Circ. 319, p. 6.

Material studied.—22 specimens from this study.

Repository.—Illinois State Geological Survey, 15P42 and 15P43 (figured specimens).

Genus FALCODUS Huddle
Type species: *Falcodus angulus* Huddle
FALCODUS? ALATOIDES Rexroad & Burton, n. sp.
Pl. 140, fig. 8

Falcodus(?) n. sp. REXROAD & COLLINSON, 1961, Illinois Geol. Survey, Circ. 319, pl. 1.

The anterior limb in this species is the shorter, and it bears approximately six appressed, laterally compressed denticles and germ denticles which incline anteriorly; the anteriormost denticle is commonly the largest, with several secondary denticles on its anterior margin as well as an aboral projection; the limb is deepest anteriorly, and it is inclined aborally from the line of the posterior limb by only about 30°. The long apical denticle is two to three times broader than adjacent denticles, and it lies nearly in the plane of the anterior limb.

The entire unit is sharply bowed and somewhat twisted, with the flexure located immediately posterior to the apical denticle. The posterior limb bears approximately ten denticles like those of the anterior limb, but they are inclined posteriorly, increasing in size toward the posterior with an aboral projection on the posteriormost.

The aboral margin of both limbs is somewhat curved and sharp. The pit is small, but it appears to be deep with the greater

expansion inward. The attachment scar is generally present on the outer face of both limbs near the aboral margin.

Remarks.—This species bears resemblances to both *Falcodus* and *Hindeodella*, differing from the former in that the anterior limb is not bent as sharply aborally as is typical, and from the latter particularly in the lack of alternation of denticle sizes on the posterior limb. Although it has the general form of *Falcodus*, it seems possible that the species represents a distinct modification of *Hindeodella*, especially in view of the fact that *Falcodus* has not been reported from extensive collections of Mississippian age.

Material studied.—29 specimens from this study.

Repository.—Illinois State Geological Survey, 15P5 (holotype), 15P62, 15P63 (paratypes).

Genus GNATHODUS, Pander
Type species: *Gnathodus mosquensis* Pander

GNATHODUS COMMUTATUS (Branson & Mehl)
Pl. 139, figs. 1–3

Spathognathodus commutatus BRANSON & MEHL, 1941, Jour. Paleontology, v. 15, p. 98, pl. 19, figs. 1–4; ——, 1941, Denison Univ. Bull., Jour. Sci. Labs, v. XXXV, p. 172, pl. V, figs. 19–22; ELLISON & GRAVES, 1941, Missouri School of Mines and Metallurgy, Bull., Tech. Ser., v. 14, no. 3, pl. 2, figs. 4,6; ELIAS, 1956, Petroleum geology of southern Oklahoma, v. 1, Am. Assoc. Petroleum Geologists, p. 119, pl. III, figs. 19–22; CLARKE, 1960, Edinburgh Geol. Soc., Trans., v. 18, pt. 1, p. 19, pl. III, figs. 4,5.

Spathognathodus inornatus (Hass) [not *S. inornatus* (Branson & Mehl), 1934], ELIAS, 1956, ibid., p. 119, pl. III, figs. 37–39.

Spathognathodus cf. *inornatus* (Hass), ELIAS, 1956, ibid., p. 119, pl. III, figs. 41,42,62,63.

Spathognathodus cf. *S. commutatus* Branson & Mehl, REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 38, pl. 3, figs. 23,24; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 26, pl. 6, fig. 8.

Gnathodus inornatus HASS, 1953, U. S. Geol. Survey, Prof. Paper 243-F, p. 80, pl. XIV, figs. 9–11; STANLEY, 1958, Jour. Paleontology, v. 32, p. 465, pl. 68, figs. 5,6.

Gnathodus commutatus commutatus (Branson & Mehl), BISCHOFF, 1957, Hess. Landesamt. Bodenf., Abhl., Hf. 19, p. 22, pl. IV, figs. 2–15; FLÜGEL & ZIEGLER, 1957, Mitt. Naturwissenschaftlichen vereines f. Steiermark, v. 87, p. 39, pl. III, fig. 21; LYS & SERRE, 1958, Inst. Franç. Pétrole, Rev., v. XIII, no. 6, p. 891, pl. IX, figs. 2a,b.; VOGES, 1959, Paläont. Zeit., v. 33, p. 281.

Material studied.—60 specimens from this study.

Repository.—Illinois State Geological Survey, 15P35, 15P65, 15P66 (figured specimens).

Genus HIBBARDELLA Bassler
Type species: *Hibbardella angulata* (Hinde)

HIBBARDELLA FRAGILIS (Rexroad)
Pl. 140, fig. 7

Trichonodella fragilis REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 40, pl. 4, figs. 6,7.

Non. *Hibbardella fragilis* HIGGINS, 1961, Geol. Mag., v. XCVIII, no. 3, p. 213,214, pl. XII, fig. 4; Text-fig. 2.

Material studied.—14 specimens from this study.

Repository.—Illinois State Geological Survey, 15P8, 15P67 (figured specimens).

HIBBARDELLA MILLERI Rexroad
Pl. 140, figs. 3,4

Hibbardella n. sp.? REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 31, pl. 1, fig. 19.

Hibbardella milleri REXROAD, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 18, pl. 2, figs. 13–16.

Twenty-three specimens differ from typical representatives of *Hibbardella milleri* in that there are only two major denticles on each limb of the arch as opposed to four or five on typical forms. Like other specimens of *H. milleri*, however, there generally are two or three minor denticles on the arch immediately anterior to the cusp. This Kinkaid variant has not been recognized in underlying beds. Perhaps future studies will indicate that it should be recognized as a separate species. It seems best at present to recognize it as a variant.

Material studied.—84 specimens from this study, 23 of which represent the above described variant.

Repository.—Illinois State Geological Survey, 15P9, 15P10, 15P68 (figured specimens).

HIBBARDELLA ORTHA Rexroad
Pl. 140, figs. 5,6

Hibbardella ortha REXROAD, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 18, pl. 2, figs. 9–12.

Material studied.—29 specimens from this study.

Repository.—Illinois State Geological Survey, 15P12, 15P69, 15P70 (figured specimens).

Genus HINDEODELLA Bassler
Type species: *Hindeodella subtilis* Ulrich & Bassler

HINDEODELLA spp.

Hindeodellid fragments are very abundant in the Kinkaid Formation, but classification of the fragments is not feasible.

Genus LAMBDAGNATHUS Rexroad
Type species: *Lambdagnathus fragilidens* Rexroad
Pl. 141, fig. 18

New genus? (part), REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 41, pl. 4, fig. 10 only.
Lambdagnathus fragilidens REXROAD, 1958, Illinois Geol. Survey Rept. Inv. 209, p. 19, pl. 6, figs. 10–16.

Material studied.—6 specimens from this study.

Repository.—Illinois State Geological Survey, 15P20 (figured specimen).

Genus LIGONODINA Bassler
Type species: *Ligonodina pectinata* Bassler

LIGONODINA HAMATA Rexroad
Pl. 141, figs. 5,6

Ligonodina hamata REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 32, pl. 1, figs. 24,25; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 21, pl. 3, figs. 9–14.
Ligonodina sp. YOUNGQUIST & MILLER (part), 1949, Jour. Paleontology, v. 23, pl. 101, fig. 11 (not figs. 12,13).
Ligonodina sp. REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 33, pl. 1, figs. 20,21.
Ligonodina tulensis (Pander), CLARKE, 1960, Edinburgh Geol. Soc., Trans., v. 18, pt. 1, p. 11, pl. II, fig. 4.

Material studied.—160 specimens from this study.

Repository.—Illinois State Geological Survey, 15P18, 15P19, 15P74 (figured specimens).

LIGONODINA LEVIS Branson & Mehl
Pl. 141, figs. 7,8

Ligonodina levis BRANSON & MEHL, 1941, Denison Univ. Bull., Jour. Sci. Labs., v. XXXV, p. 185, pl. VI, fig. 10; BISCHOFF, 1957, Hess. Lamdesamt. Bodenf., Abhl., Hf. 19, p. 30, pl. 5, figs. 8,9, pl. 6, fig. 25.
Ligonodina obunca REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 32, pl. 1, figs. 22,23; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 21, pl. 3, figs. 7,8.
Ligonodina sp. YOUNGQUIST & MILLER (part), 1949, Jour. Paleontology, v. 23, p. 620, pl. 101, figs. 12,13 (not fig. 11).

Material studied.—86 specimens from this study.

Repository.—Illinois State Geological Survey, 15P75, 15P76, 15P77 (figured specimens).

LIGONODINA n. sp.?
Pl. 141, figs. 2–4

Representatives of this questionable species possess a straight posterior bar which bears discrete denticles that are erect or directed slightly posteriorly. The denticles are pointed, biconvex in section, and almost as wide as the bar at their base. The denticles tend to alternate in size. The main cusp is pointed, biconvex in section, nearly erect to somewhat recurved, and has a basal portion that is aboral to the level of the posterior bar. The inner lateral process emerges from the basal portion of the anterior edge of the main cusp, and is directed inward. It is twisted so that the distal margin as viewed laterally forms an angle of 30° to 40° with the posterior bar. The inner lateral process supports two major denticles. The proximal one generally is the larger, and a small denticle is located directly anterior to the main cusp. The denticles are nearly round in cross section, are recurved, and are inclined anteriorly. The aboral margin of this form has a median groove that is slightly expanded below the main cusp. An inner lateral ridge and outer lateral lip tend to separate the aboral surface from the part of the specimen that lies below the anticusp and adjoins part of the posterior bar.

This ligonodinid differs from *Ligonodina fragilis* Hass especially in the lesser number of denticles of the inner lateral process. It differs from *L. tenuis* Branson & Mehl and *L. hamata* Rexroad in the same manner as well as in the longer more nearly uniform posterior bar. However, it is so closely similar to all three of these species as well as to an unnamed ligonodinid from the Caney shale that the validity of considering this a separate species is questionable.

The species is not known below the Kinkaid Formation. Within the Kinkaid it has been recognized in units A, C, and D, but is abundant only in the uppermost unit. Its

stratigraphic development suggests evolution from *Ligonodina hamata*.

Material studied.—63 specimens.

Repository.—Illinois State Geological Survey, 15P71, 15P72, 15P73 (figured specimens).

Genus NEOPRIONIODUS Rhodes & Müller
Type species: *Prioniodus conjunctus* Gunnell

NEOPRIONIODUS CAMURUS Rexroad
Pl. 140, fig. 11

Neoprioniodus camurus REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 33, pl. 2, figs. 18–20; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 23, pl. 5, figs. 5,6.

Material studied.—57 specimens from this study.

Repository.—Illinois State Geological Survey, 15P21, 15P78 (figured specimens).

NEOPRIONIODUS LOXUS Rexroad
Pl. 140, fig. 12

Neoprioniodus loxus REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 34, pl. 2, figs. 8,9,14; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 23, pl. 5, figs. 7–9.

Neoprioniodus tenuis REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 35, pl. 2, figs. 13,16.

Material studied.—34 specimens from this study.

Repository.—Illinois State Geological Survey, 15P25 (figured specimen).

NEOPRIONIODUS SCITULUS (Branson & Mehl)
Pl. 140, figs. 15–17

Prioniodus scitulus BRANSON & MEHL, 1940, Denison Univ. Bull., Jour. Sci. Labs., v. XXXV, p. 173, pl. V, figs. 5,6; COOPER, 1947, Jour. Paleontology, v. 21, p. 92, pl. 20, figs. 1–3; ELIAS, 1956, Petroleum geology of southern Oklahoma: Am. Assoc. Petroleum Geologists, v. 1, p. 109, pl. II, figs. 9,10.

Neoprioniodus scitulus (Branson & Mehl) REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 35, pl. 2, figs. 22,26; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 23, pl. 5, figs. 10–14; ELIAS, 1959, Geology of the Ouachita Mountains: Dallas Geol. Society-Ardmore Geol. Society, p. 151, pl. II, figs. 6,7.

Neoprioniodus striatus REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 35, pl. 2, figs. 11,12.

Neoprioniodus cassilaris (Branson & Mehl) ELIAS (part), 1959, Geology of the Ouachita Mountains: Dallas Geol. Society-Ardmore Geol. Society, p. 153, pl. II, figs. 20,21.

Material studied.—485 specimens from this study.

Repository.—Illinois State Geological Survey, 15P26, 15P79, 15P80 (figured specimens).

NEOPRIONIODUS SINGULARIS (Hass)
Pl. 140, figs. 13,14,18

Prioniodus signularis HASS, 1953, U. S. Geol. Survey, Prof. Paper 243-F, p. 88, pl. 16, fig. 4.

Neoprioniodus singularis (Hass), STANLEY, 1958, Jour. Paleontology, v. 32, n. 3, p. 471, pl. 66, figs. 2,3.

Prioniodus barbatus Branson & Mehl, ELLISON & GRAVES (part), 1941, Missouri School of Mines & Metallurgy, Bull., Tech. Ser., v. 14, no. 3, pl. 1, fig. 25 only (not fig. 27).

Prioniodus roundyi var. *dividen* ELIAS, 1956, Petroleum geology of southern Oklahoma: Am. Assoc. Petroleum Geologists, p. 110, pl. II, figs. 39–41.

Prioniodus roundyi cf. var. *parviden* ELIAS, 1956, ibid., p. 112, pl. II, figs. 42,43.

Prioniodus cf. *singularis* Hass, ELIAS, 1956, ibid., p. 112, pl. II, fig. 45.

Prioniodina alatoidea (Cooper), BISCHOFF, 1957, Hess. Landesamt. Bodenf., Abhl., Hf. 19, p. 45, pl. 5, figs. 33,34,36.

Material studied.—28 specimens from this study.

Repository.—Illinois State Geological Survey, 15P22, 15P23, 15P24, 15P81 (figured specimens).

NEOPRIONIODUS VARIANS (Branson & Mehl)
Pl. 140, figs. 9,10

Prioniodus varians BRANSON & MEHL, 1940, Denison Univ. Bull., Jour. Sci. Labs., v. XXXV, p. 174, pl. V, figs. 7,8.

Prioniodina varians (Branson & Mehl), BISCHOFF, 1957, Hess. Landesamt. Bodenf., Abhl., Hf. 19, p. 49, pl. V, fig. 35; FLÜGEL & ZIEGLER, 1957, Naturwissenschaftlichen vereines f. Steiermark, Mitteil. Bd. 87, p. 50.

Neoprioniodus varians (Branson & Mehl), REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 35, pl. 2, fig. 10; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 24, pl. 5, figs. 3,4.

Prioniodus barbatus Branson & Mehl, ELLISON & GRAVES (part), 1941, Missouri School of Mines & Metallurgy, Bull., Tech. Ser., v. 14, n. 3, pl. 1, fig. 27 only (not fig. 25).

Nearly half the Kinkaid specimens assigned to *Neoprioniodus varians* differ from more characteristic specimens from that formation and the underlying Chester formations. Specimens of the Kinkaid variant conform more closely to the Caney holotype in that they have no germ denticles. Further-

more, the anticusp is more prominent and the posterior bar is thicker and lower than in representative Kinkaid forms. These differences fall within the normal range of variation of the species, and although the group with these characteristics is quite distinctive, it seems best not to consider it a new species.

Material studied.—34 specimens from this study, 16 of which belong to the variant group.

Repository.—Illinois State Geological Survey, 15P27, 15P82 (figured specimens).

Genus OZARKODINA Branson & Mehl
Type species: *Ozarkodina typica* Branson & Mehl

OZARKODINA COMPRESSA Rexroad
Pl. 141, figs. 16,17

Ozarkodina compressa REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 36, pl. 2, figs. 1,2; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 24, pl. 6, figs. 1,2.

Material studied.—23 specimens from this study.

Repository.—Illinois State Geological Survey, 15P30, 15P83 (figured specimens).

OZARKODINA CURVATA Rexroad
Pl. 141, figs. 13,14

Ozarkodina curvata REXROAD, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 24, pl. 4, figs. 1–3.

Material studied.—42 specimens from this study.

Repository.—Illinois State Geological Survey, 15P31, 15P84 (figured specimens).

OZARKODINA DELICATULA (Stauffer & Plummer)
Pl. 141, fig. 12

For synonomy see: RHODES, F. H. T., 1952, Jour. Paleontology, v. 26, p. 893.

Although *Ozarkodina delicatula* has not previously been recognized in rocks of Mississippian age, it is likely that it will be found both lower in the section than the Kinkaid and in areas other than that of the present study. In the Glen Dean Formation it was noted that a few of the specimens described as *O. compressa* were markedly more elongate and slightly less arched than the average (Rexroad, 1958). Such specimens may be referable to *O. delicatula*. Ozarkodinids tend to be more fragile than many genera, yet more nearly complete specimens are needed for accurate identification.

Material studied.—7 specimens from this study.

Repository.—Illinois State Geological Survey, 15P29 (figured specimen).

Genus SPATHOGNATHODUS Branson & Mehl
(SPATHODUS Branson & Mehl)
Type species: *Spathodus primus* Branson & Mehl

SPATHOGNATHODUS CAMPBELLI Rexroad
P. 141, fig. 15

Spathognathodus campbelli REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 37, pl. 3, figs. 13–15; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 25, pl. 6, fig. 9.

Material studied.—8 specimens from this study.

Repository.—Illinois State Geological Survey, 15P34 (figured specimen).

SPATHOGNATHODUS CRISTULA Youngquist & Miller
Pl. 141, fig. 9

Spathognathodus cristula YOUNGQUIST & MILLER, 1949, Jour. Paleontology, v. 23, p. 621, pl. 101, figs. 1–3; REXROAD, 1957, Illinois Geol. Survey, Rept. Inv. 199, p. 38, pl. 3, figs. 16,17; ——, 1958, Illinois Geol. Survey, Rept. Inv. 209, p. 25, pl. 6, figs. 3,4.

Spathognathodus minutus (Ellison), ELLISON & GRAVES, 1941, Missouri School of Mines and Metallurgy, Bull., Tech. Ser., v. 14, no. 3, pl. II, figs. 1,3,5.

Material studied.—304 specimens from this study.

Repository.—Illinois State Geological Survey, 15P36, 15P85 (figured specimens).

SPATHOGNATHODUS MINUTUS (Ellison)
Pl. 141, figs. 10,11

Spathodus minutus ELLISON, 1941, Jour. Paleontology, v. 15, p. 120, pl. 20, figs. 50–52.

Spathognathodus minutus (Ellison), YOUNGQUIST & DOWNS, 1949, Jour. Paleontology, v. 23, p. 169, pl. 30, fig. 4; STURGEON & YOUNGQUIST, 1949, Jour. Paleontology, v. 23, p. 385, pl. 74, figs. 9–11, pl. 75, fig. 19.

Spathognathodus minutus is one of an evolutionary series of spathognathodids which includes an unnamed species from the Valmeyer series, *S. cristula* from the Chester, and *S. minutus* from the Pennsylvanian. There is further the possibility that the sequence goes back to *S. regularis* (Branson & Mehl) from the Kinderhook. The naval is central in the earlier forms but it extends all the way to the posterior in the later species. Except for this difference

and the presence of secondary denticles along the anterior margin of most representatives of *S. minutus*, the Kinkaid species is nearly identical with the Valmeyer form. The aboral margin of the blade of *S. minutus* when viewed laterally is inclined aborally toward the anterior, giving an arched appearance not found in *S. cristula;* this, together with a difference in oral outline and a complete lack of secondary denticles on the anterior margin of *S. cristula*, serves to distinguish the two species. In association with *Streptognathodus* this species may indicate a Pennsylvanian age for unit D of the Kinkaid. It has not been reported previously from beds below the Pennsylvanian.

Material studied.—8 specimens from this study.

Repository.—Illinois State Geological Survey, 15P37, 15P38 (figured specimens).

Genus STREPTOGNATHODUS Stauffer & Plummer

Type species: *Streptognathodus excelsus* Stauffer & Plummer

STREPTOGNATHODUS UNICORNIS Rexroad & Burton, n. sp.

Pl. 138, figs. 1–9

Taphrognathus varians Branson & Mehl, COOPER, 1947, Jour. Paleontology, v. 21, p. 92, pl. 20, figs. 14–16.

Oral view. The unit is slightly and regularly bowed; the platform is narrow and lanceolate in shape, the outer parapet is convex, the inner parapet is nearly straight; the parapets are ornamented by parallel transverse ridges that do not extend into the median trough except near the posterior tip where opposite ridges may coalesce, and the posterior one or two may be nodelike. The blade is median (except in some forms believed to be transitional with *Cavusgnathus*). It is very nearly one-half the total length of the specimen and does not continue on to the platform as a carina. The blade is thickest posteriorly. Its denticles are laterally compressed.

Lateral view.—The unit is unarched except in atypical specimens; the parapets are slightly convex and sharply set off from the blade by a notch in the oral surface at the anterior end of the platform; the blade has varying numbers of denticles but the average is eight that are appressed and fused nearly to their apices. The posterior denticle is the largest. The remainder are subequal in height except the anteriormost denticle which is generally very small.

Aboral view.—The navel is elongate with a slightly greater flare on the outer lip. The navel begins under the posteriormost one or two denticles of the blade and extends to the posterior tip. It is of moderate depth, with its greatest depth near the anterior; it is widest anterior to its midlength. A faint median groove is generally present on the aboral margin of the blade.

Remarks.—This species is considered to have been derived from *Cavusgnathus* because of the demonstrated migration of the blade from alignment with the outer parapet to a central position. The retention of a prominent posterior denticle on the blade along with the regularity of ornamentation of the parapets suggest *C. unicornis* rather than *C. navicula* as the ancestral form. Lack of nodose accessory lobes and a distinct deep median trough are considered primitive characteristics.

This species is similar to *Streptognathodus primus* Elias which seems to have a comparable stratigraphic distribution. Whether the two represent separate evolutionary developments is conjectural. *S. primus* lacks the prominent posterior blade denticle of *S. unicornis*, has a proportionately longer blade, and has a less symmetrical navel. Furthermore, the oral surface of the blade, rather than the aboral surface, is aligned with the platform as viewed laterally.

Material studied.—217 specimens.

Repository.—Illinois State Geological Survey, 15P39 (holotype), 15P40, 15P86-15P90 (paratypes), 15P41, 15P91 (figured specimens transitional with *Cavusgnathus*).

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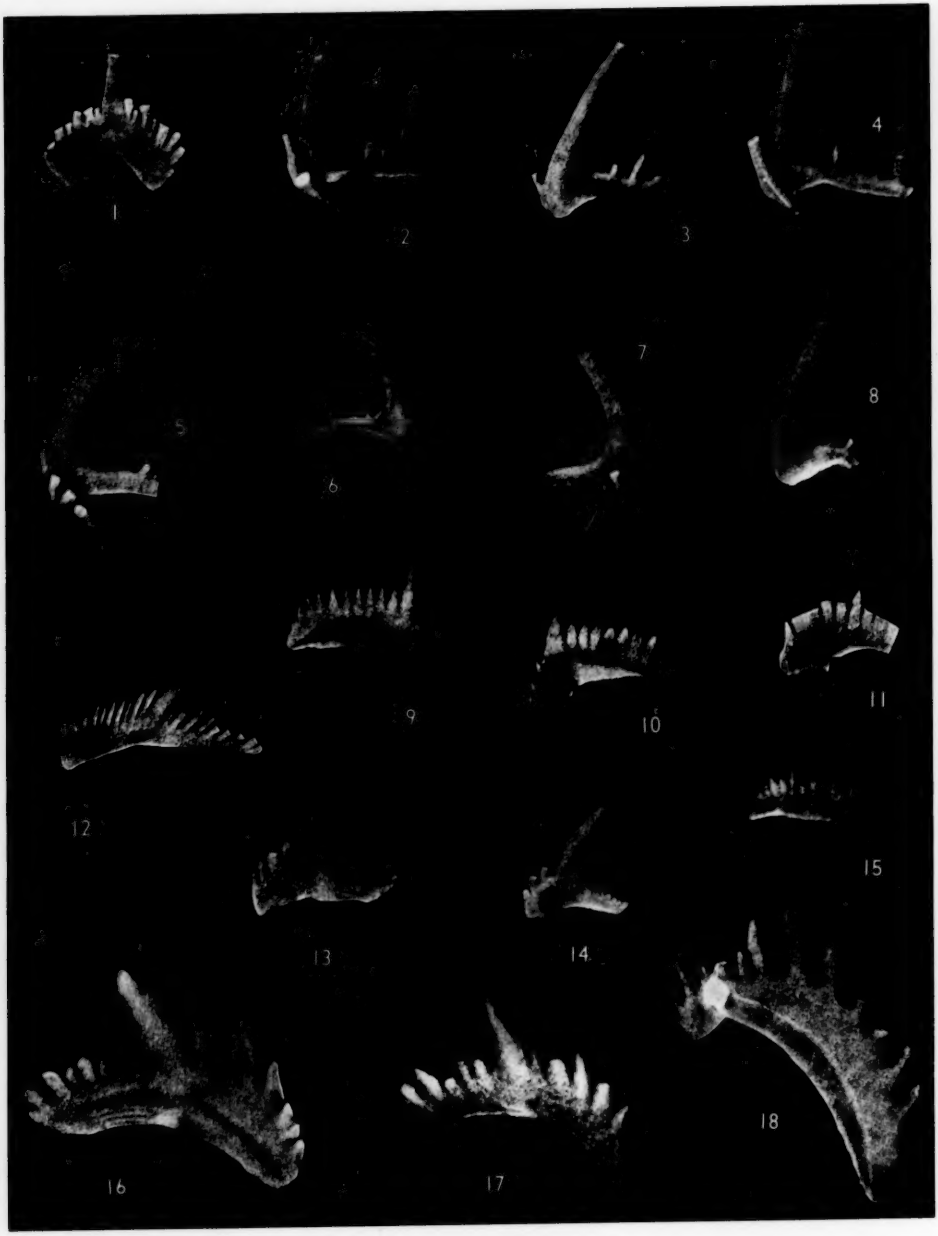
EXPLANATION OF PLATE 141

Numbers in parentheses after explanations refer to locality and sample numbers; for example, (1–18) refers to locality 1, sample 18. All figures are magnified ×40.

FIGS. *1—Elsonella? imperfecta* (Rexroad). Posterior view (1–18).
2–4—Ligonodina n. sp.?. Inner, outer, and inner lateral views (2–12, 2–32, 2–12).
5,6—Ligonodina hamata Rexroad. *5*, Inner lateral view (2–30); and *6*, lateral view of young specimen (1–1 to 3 composite).
7,8—Ligonodina levis Branson & Mehl. Inner and outer lateral views (both 1–4 to 6 composite).
9—Spathognathodus cristula Youngquist & Miller. Inner lateral view (2–32).
10,11—Spathognathodus minutus (Ellison). Inner lateral views (2–10, 2–8).
12—Ozarkodina delicatula (Stauffer & Plummer). Inner lateral view (2–8).
13,14—Ozarkodina curvata Rexroad. Inner lateral views (1–13, 1–4 to 6 composite).
15—Spathognathodus campbelli Rexroad. Outer lateral view (2–26).
16,17—Ozarkodina compressa Rexroad. Inner and outer lateral views (1–6, 1–4 to 6 composite).
18—Lambdagnathus fragilidens Rexroad. Anterior view (2–20).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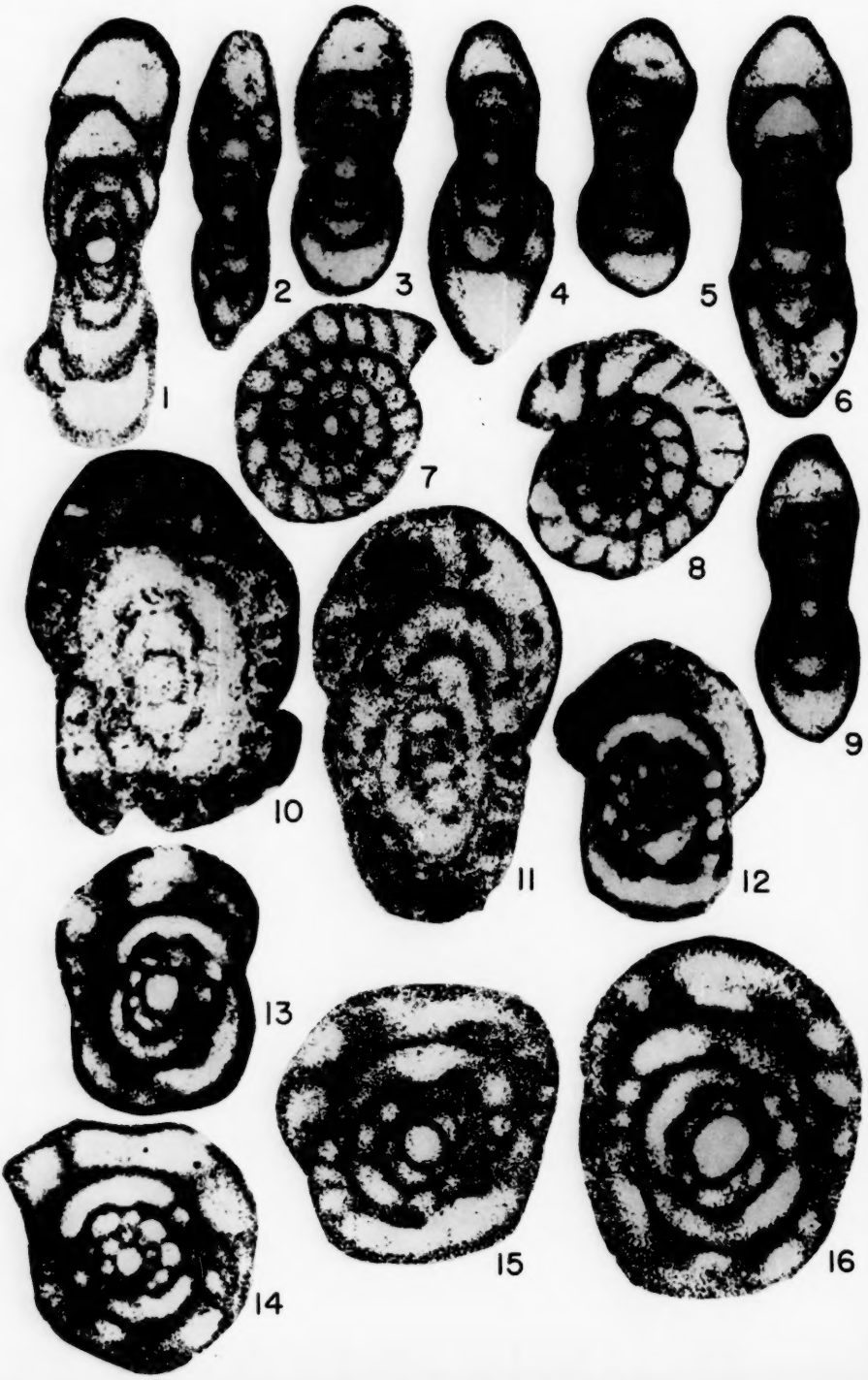
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JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1159–1180, PLS. 142–146, 4 TEXT-FIGS., NOVEMBER, 1961

STRATIGRAPHIC SECTION AND FUSULINIDS OF THE BIRD SPRING FORMATION NEAR LEE CANYON, CLARK COUNTY, NEVADA

MARK RICH
University of North Dakota, Grand Forks

ABSTRACT—The thick section of the Bird Spring formation near Lee Canyon, Clark County, Nevada, consists of more than 7000 feet of predominantly carbonate beds that show no apparent major lithologic breaks. Megafossils collected from the basal 500 feet indicate that the lower 100 feet are Chesterian in age and that the Mississippian-Pennsylvanian boundary occurs within a transitional interval. Fusulinids collected from the remaining 6500 feet of the formation indicate that all of the following divisions of the Pennsylvanian and Permian are represented: Morrowan, Atokan, Desmoinesian, Missourian, Virgilian, Wolfcampian, and Leonardian. The Pennsylvanian-Permian boundary is gradational. A total of 2600 feet of Chesterian and Pennsylvanian beds are present, and 4500 feet of Permian are present. The lack of important lithologic breaks and the presence of all major fusulinid zones indicate that deposition of the predominantly carbonate Bird Spring formation was continuous from late Mississippian time, through all of Pennsylvanian time, and into at least the Leonardian part of the Permian Period. The upper limits of the Bird Spring formation could not be determined because of truncation by faulting.

Fusulinids representing Wolfcampian and Leonardian from the upper 3800 feet of the formation were identified by Christy (1958) and include several species of *Schwagerina* and one species each of *Pseudoschwagerina*, *Pseudofusulina*, and *Parafusulina*. Fusulinids representing the Pennsylvanian and part of the Wolfcampian were identified in the present study from the lower 3300 feet of the formation and include the following: *Millerella marblensis*, one unidentified species of *Staffella*, forms of *Pseudostaffella*, *Profusulinella decora*, *Fusulinella devexa*, *Fusulina similis*, *Bartramella bartrami*, two unnamed species of *Pseudofusulinella*, several species of *Triticites*, one form questionably referred to *Dunbarinella*, several species of *Schwagerina*, *Pseudoschwagerina texana*, and an unidentified form of *Parafusulina*.

INTRODUCTION

DURING late Mississippian, Pennsylvanian, and Permian times, several thousand feet of predominantly carbonate sediments accumulated in southern Nevada and southeastern California. Because of their lithologic unity these rocks constitute a single formation, the Bird Spring formation. One of the best sections is exposed along the eastern front of Spring Mountains about 35 miles northwest of Las Vegas and 1.4 miles northwest of Lee Canyon, Clark County, Nevada (Text-fig. 1). It extends from the NE¼ sec. 34, T. 17 S., R. 57 E. through secs. 27, 28, 21, 20, and 17, T 17 S., R. 57 E. in the Charleston Peak Quadrangle (Text-fig. 2). There the formation is greater than 7000 feet thick; it is broken only by minor faults, and it contains a prolific fusulinid fauna.

EXPLANATION OF PLATE 142

All figures ×100

FIGS. *1–9*—*Millerella marblensis* Thompson. *1–6,9*, Axial sections, hypotypes, Univ. Ill. nos. ×1400, ×1400d, ×1400e, ×1400f, ×1400g, ×1400h, ×1400e; and *7,8*, equatorial sections, hypotypes, Univ. Ill. nos. ×1400a, ×1400b. *2–5,7,9*, are from bed 44; *8* is from bed 50; *6* is from bed 49; and *1* is from bed 109.

10,11—*Staffella* sp. *10,11*, axial sections, Univ. Ill. nos. ×1401a, ×1401. Both from bed 85.

12,13—*Pseudostaffella needhami* Thompson. *12,13*, Axial sections, hypotypes, Univ. Ill. nos. ×1402a, ×1402. Both from bed 166.

14–16—*Pseudostaffella* spp. *14–16*, Axial sections, Univ. Ill. nos. ×1403, ×1403b, ×1403a. *14* is from bed 85; and *15,16* are from bed 44.

This report deals with that thick stratigraphic section and its contained fusulinids. An attempt has been made to correlate the various divisions with units in the mid-continent region where the most extensive studies on fusulinids have been made.

PREVIOUS WORK

Hewett (1931) first described the formation from exposures in the Bird Spring Range, Nevada, where it consists of 2500 feet of predominantly carbonate beds. He assigned the entire sequence to the Pennsylvanian on the basis of Girty's identifications of fossils collected primarily from the lower half of the formation. Later, Longwell & Dunbar (1936a, 1936b) noted that the formation thickens northward from the type locality to 5250 feet in the Spring Mountains (near Lee Canyon), northwest of Las Vegas, where it rests on the lower and middle Mississippian Monte Cristo limestone. They made a generalized study of fusulinids in the formation and subdivided the section into five major lithologic units. Each of these units, with the exception of the lowest, grossly corresponded to a fusulinid zone. The upper two units were reported by them to be 2,950 feet in total thickness and to comprise the Zones of *Schwagerina* and *Pseudoschwagerina*. These were correlated with the Wolfcamp and Leonard formations of Texas. The next lower unit comprised the Zone of *Triticites* and was assigned to the Upper Pennsylvanian. The lowest fusulinid bearing member corresponded to the Zone of *Fusulinella* (Middle Pennsylvanian). These upper four members were reported to consist predominantly of carbonate beds. Longwell & Dunbar found no fusulinids in the more clastic basal 700 feet of the formation, which they named the Indian Springs member of the Bird Spring formation. They regarded the Indian Springs member as Chesterian in age on the basis of an unpublished report by Girty on the fauna from that member. The Mississippian-Pennsylvanian boundary was arbitrarily placed below the first occurrence of *Fusulinella*.

Later, Hazzard (1938, 1951, 1954) referrred Pennsylvanian rocks in the Nopah-Resting Springs Mountains in southeastern California to the Bird Spring formation. In 1946 Thompson & Hazzard published on the Permian fusulinids from the middle portion of the Bird Spring formation in the Providence Mountains of southeastern California. Wolfcampian and possibly Leonardian ages were assigned to the section.

Since the early reconnaissance work of King (1878), Hague (1883, 1892), and Walcott (1884) in east-central Nevada, increasing work has been done in the Great Basin on rocks occupying the same stratigraphic position as the Bird Spring formation. In 1953, Easton et al. summarized existing knowledge of stratigraphic units in the Great Basin, and in his summary of Pennsylvanian stratigraphy in Nevada, Dott (1955) correlated late Mississippian, Pennsylvanian, and early Permian formations in the same region. Nolan, Merriam & Williams (1956) restudied the formations in the Eureka area, Nevada, and suggested several revisions for that standard stratigraphic section. In the same year, Hewett (1956) described the section in the Ivanpah Quadrangle, California and Nevada. Merriam & Hall (1957) published on the Pennsylvanian and Permian rocks of the southern Inyo Mountains, California. They redefined units studied earlier by Kirk (1918) and named the units there the Keeler Canyon formation (Pennsylvanian and lower Permian) and Owens Valley formation (Permian). Stratigraphic zonation was based on fusulinids, and correlation was made with most of the Bird Spring formation.

Although stratigraphic knowledge of late Paleozoic rocks from the Great Basin and immediately adjacent areas is increasing, few detailed studies on fusulinids have been published. Thompson, Verville & Bissell (1950) described Pennsylvanian fusulinids of the Oquirrh formation in the south-central Wasatch Mountains, Utah. In his report on Wolfcampian fusulinids Thompson (1954) listed forms from Fusulina Peak in Eureka County, Nevada, from the Confusion Range of western Utah, from a section near Wells, Nevada, and from the Wasatch Mountains of Utah. He later identified specimens for a report by Youngquist & Haegele (1955) on Pennsylvanian-Permian fusulinid bearing beds in the Sublett Range, south-central Idaho. In a study of the Pennsylvanian and Permian stratigraphy of the Wood River formation of south-central

Idaho, Bostwick (1955) listed several fusulinid species. In the Conger Mountains of the Confusion Range in western Utah, Thompson & Zeller (1956) found *Profusulinella* associated with species of *Staffella* and *Millerella*. Knight (1956) described fusulinids from the Arcturus formation (Permian) in east-central Nevada, and in the same year, Verville, Thompson, & Lokke (1956), working also in eastern Nevada, reported on Pennsylvanian fusulinids from the Ely limestone. In 1958, Thompson, Dodge, & Youngquist studied in more detail collections made earlier by Youngquist & Haegele in the Sublett Range, Idaho.

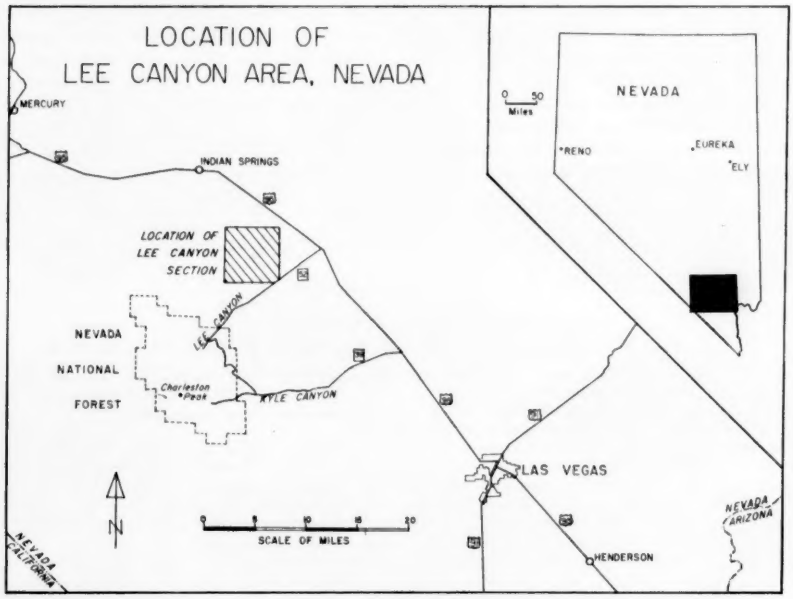
PRESENT WORK

During the summer of 1957, two months were spent in carefully measuring and describing the thick section of the Bird Spring formation near Lee Canyon. Descriptions were made of each bed, and fossils were collected. Emphasis was placed on collecting fusulinids, although great effort was made to procure megafossils from the lower 500 feet of the formation where no fusulinids were found. Approximately 790 units were delineated (including concealed intervals). The upper part of the formation was not exposed because of truncation by faulting.

Fusulinid collections from the upper 3800 feet of the section were studied by Christy (1958). Christy's findings are discussed in a later section of this report. Several hundred thin sections were prepared and studied from the many collections in the lower half of the formation.

ACKNOWLEDGMENTS

The writer is especially indebted to Harold R. Wanless of the University of Illinois for rendering advice and information before and during the field study. Harold W. Scott of the same University graciously furnished advice and criticism which were valuable in preparation of this report. William H. Easton of the University of Southern California identified the megafossils from the Indian Springs member of the Bird Spring formation and provided in-



TEXT-FIG. 1—Index map.

formation regarding their age relationships. Special thanks are due to M. L. Thompson of the Illinois State Geological Survey for making helpful suggestions regarding the content of this report and procedures in fusulinid studies, and for critically reading the manuscript. Joseph LoBue, personal friend of the writer, unselfishly allowed use of his jeep during the entire field study. The writer's wife, Symma C. Rich, typed the original draft of the manuscript and gave constant encouragement during its preparation. Financial aid for this investigation was given by the University of Illinois Research Board.

GENERAL LITHOLOGY

Because it is so continuously well exposed, has a rather uniform 25 to 35 degree northwesterly dip, and seemingly is broken only by minor faults, the Bird Spring section lends itself nicely to description and measurement. The base of the formation rests on what is here considered to be the equivalent of the Yellowpine limestone member of the Mississippian Monte Cristo limestone (Text-fig. 4).

As aforementioned, Longwell & Dunbar (1936b) subdivided the Bird Spring formation in the Spring Mountains north of Las Vegas into five members which were more or less gradational with one another. These lithologic divisions are recognized in the measured section; however, no attempt is made here to place them in member status.

After this paper was written, Bissell (1960) published a correlation chart and several diagrams relating to distribution of Permo-Pennsylvanian strata in the eastern Great Basin. He subdivided the Bird Spring as defined herein into three formations which are in ascending order: the Illipah (earliest Pennsylvanian), "Bird Spring" (Pennsylvanian), and the Spring Mountain (Wolfcampain and Leonardian). If further areal studies show that such subdivision is tenable, then the present writer would suggest raising the Bird Spring to group status and applying suitable formation names to its units.

The lowest unit consists of 100 feet of quartzitic sandstone interbedded with medium and coarse-grained fossiliferous limestone and silty and shaly limestone. At the base are 15 feet of sandstone with thin interbeds of limestone. Fault A repeats some of the lowest beds along with the top 100 feet of the Monte Cristo limestone (Text-figs. 2 and 4).

The next higher sequence consists of 2200 feet of fossiliferous limestone interbedded with arenaceous, silty, and shaly limestone and calcareous shale. Nodular chert is abundant throughout most of the sequence. Slopes cut into these beds are rough and irregular. Fault B repeats the upper 400 feet of this interval (Text-figs. 2 and 4).

Massive ledge forming limestone alternating with zones of unresistant silty and shaly limestone constitute the next higher

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EXPLANATION OF PLATE 143

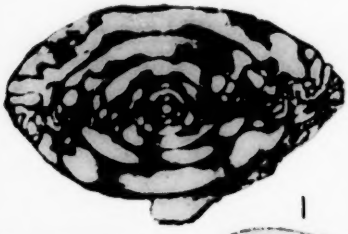
All figures ×20 except *5*, *9*, and *12*, which are ×140, ×100, and ×100, respectively.

FIGS. *1–5*—*Profusulinella decora* Thompson. *1,4*, Axial sections, hypotypes, Univ. Ill. nos. ×1404, ×1404a; *2*, sagittal section, hypotype, Univ. Ill. no. ×1404f; *3*, tangential section, hypotype, Univ. Ill. no. ×1404c; and *5*, enlarged portion of specimen illustrated in *1* to show wall structure. All specimens are from bed 109.

6–9—*Fusulinella devexa* Thompson. *6,7*, Axial sections, hypotypes, Univ. Ill. nos. ×1405, ×1405e; *8*, tangential section, hypotype, Univ. Ill. no. ×1405d; and *9*, enlarged portion of a specimen not illustrated to show wall structure. All specimens are from bed 171.

10–12—*Fusulina similis* Galloway & White. *10*, Axial section, hypotype, Univ. Ill. no. ×1406; *11*, sagittal section, hypotype, Univ. Ill. no. ×1406c; and *12*, enlarged portion of *10* illustrated to show wall structure. All specimens are from bed 242.

13–18—*Bartramella bartrami* Verville, Thompson & Lokke. *13,15,16,18*, Axial sections, hypotypes, Univ. Ill. nos. ×1407a, ×1407b, ×1407e, ×1407, ×1407d, ×1407i, ×1407c; *14*, tangential section, hypotype, Univ. Ill. no. ×1407h; and *17*, sagittal section, hypotype, Univ. Ill. no. ×1407f. All specimens are from bed 252.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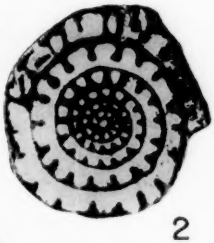
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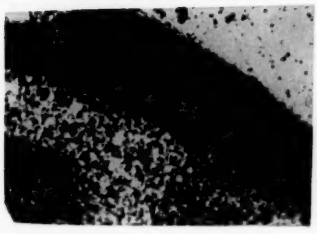
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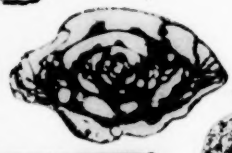
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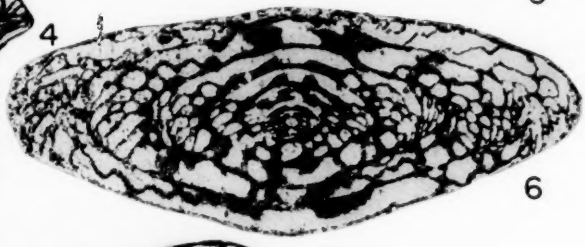
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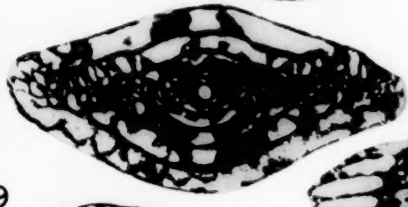
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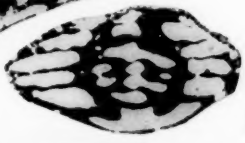
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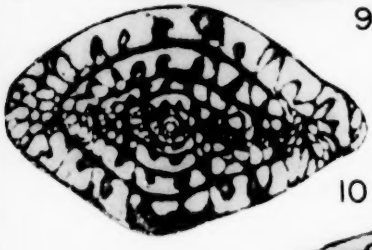
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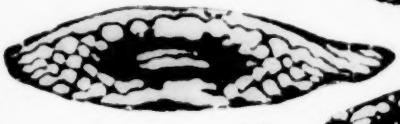
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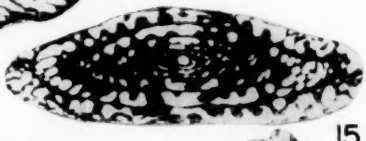
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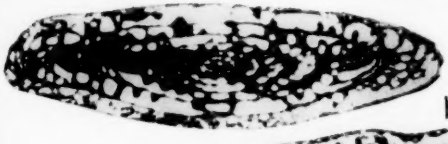
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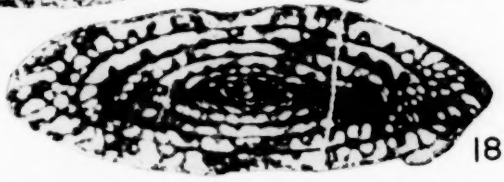
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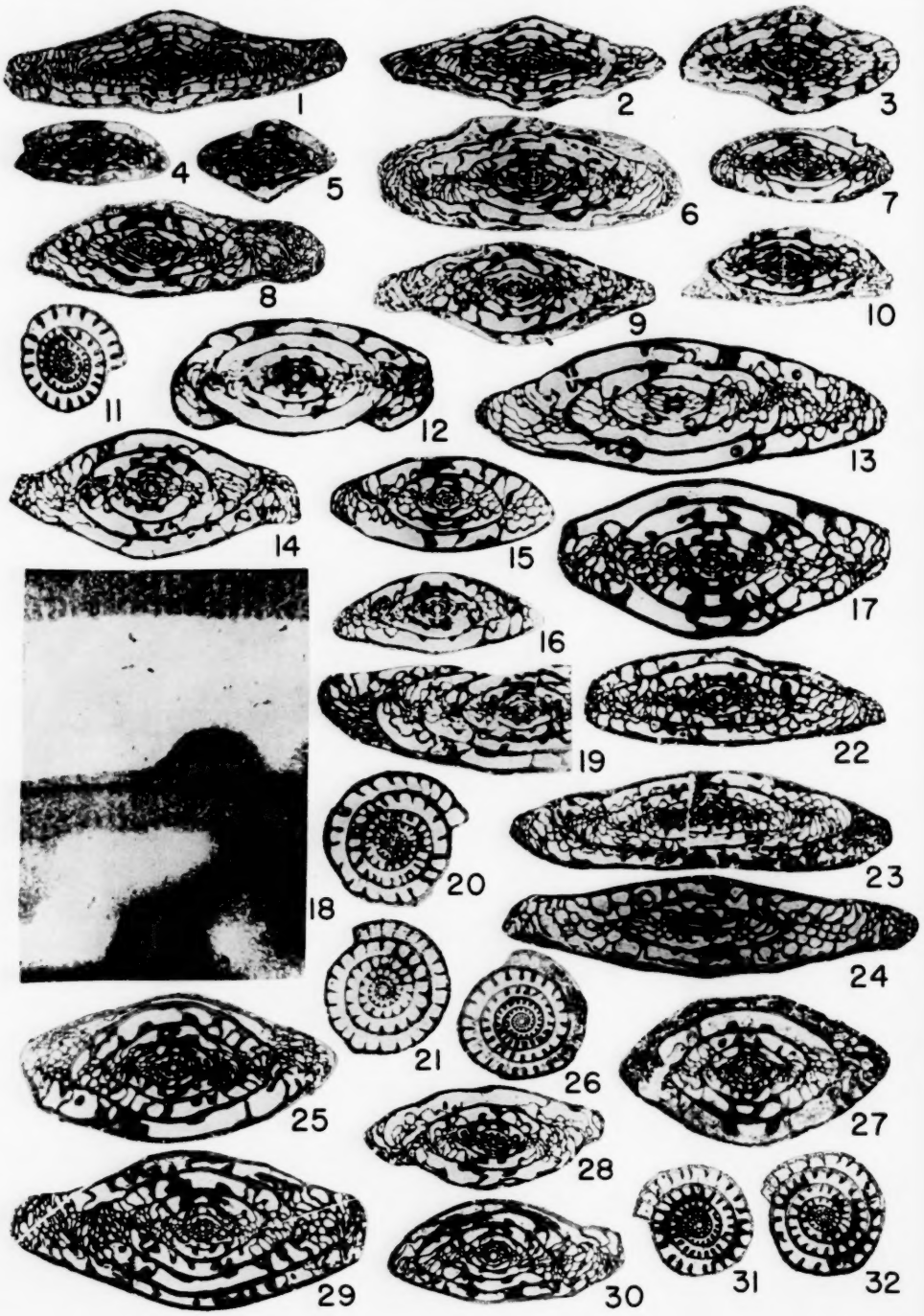
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sequence, which is 965 feet thick. On mountain slopes this unit is expressed by a regular steplike alternation of resistant limestone ledges and intervening more gentle smooth slopes.

The succeeding unit consists of 2450 feet of arenaceous, silty, and platy limestone which forms yellow-brown and buff-colored smooth slopes that are broken at various intervals by ledges of more resistant limestone. The contact between this and the underlying sequence is rather abrupt. A few beds near the top of the unit are locally contorted along small faults.

Dark-gray and black limestone constitutes most of the highest sequence which is gradational with the underlying rocks. Arenaceous, silty, and shaly limestone are interbedded in the lower portion but decrease toward the top where the limestone beds are relatively massive and resistant. Chert is abundant throughout the unit. Faults C and D (Text-figs. 2 and 3) disrupt the middle of the unit; however, they seem to be of small displacement and extent. Fault E (Text-figs. 2 and 3) truncates the top of this interval, and the exposed thickness of 1350 feet is a minimum. The fault repeats beds which apparently belong to this highest part of the formation. These beds dip vertically adjacent to the north side of the fault. Northwest from the fault they decrease in dip and are overturned steeply to the northwest as shown on the geologic map of Clark County, Nevada, prepared by Bowyer, Pampeyan, and Longwell (1958).

The lowest unit described in the preceding paragraphs corresponds to the basal portion of the Indian Springs member described by Longwell & Dunbar. The next higher unit is equivalent to the upper part of the Indian Springs member and all of member number 2 of Longwell & Dunbar. The upper three units correspond to their members 3, 4, and 5, respectively.

It is not known to what extent the faults disturbing the upper part of the Bird Spring formation alter the 7000 foot exposed thickness calculated for the formation. Major fusulinid zones do not appear to be repeated. If omission of some strata has occurred, the indicated thickness would then be a minimum one.

FAUNAL SUMMARY AND STRATIGRAPHIC CORRELATION

No fusulinids were found in the lower 515 feet of the Bird Spring formation. Age relationships of these beds has long been problematical because the transition be-

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EXPLANATION OF PLATE 144

All figures ×10.5, except *18* which is ×120

FIGS. *1–3—Pseudofusulinella* sp. A. *1–3*, Axial sections, Univ. Ill. nos. ×1408, ×1408a, ×1408b. All from bed 132A.

4,5—Pseudofusulinella sp. B. *4,5*, Axial sections, Univ. Ill. nos. ×1409, ×1409a. Both from bed 86A.

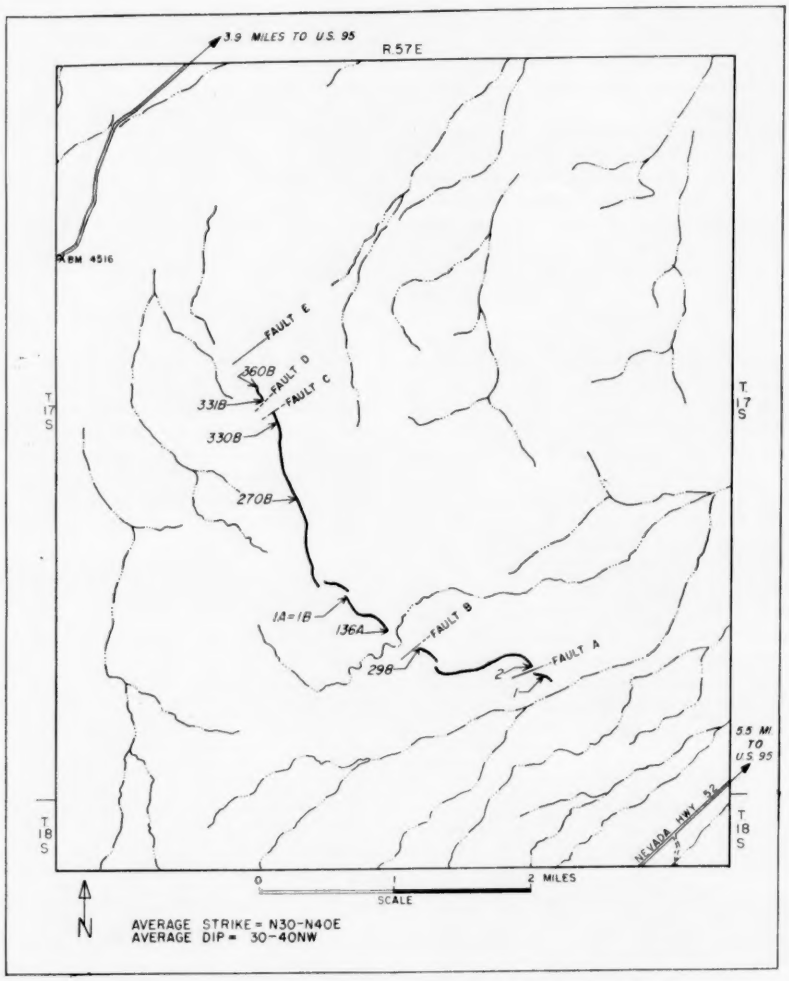
6–11—Triticites springvillensis Thompson, Verville & Bissell. *6–10*, Axial sections, hypotypes, Univ. Ill. nos. ×1410, ×1410e, ×1410a, ×1410b, ×1410d; *11*, sagittal section, hypotype, Univ. Ill. no. ×1410c, *6,8–11* are from bed 258; and *7* is from bed 262.

12–21—Triticites gallowayi Needham. *12, 14–17,19*, Axial sections, hypotypes, Univ. Ill. nos. ×1411, ×1411e, 1411g, ×1411f, ×1411h, ×1411c; *13*, tangential section, hypotype, Univ. Ill. no. ×1411a; *20,21*, sagittal sections, hypotypes, Univ. Ill. nos. ×1411b, ×1411i; and *18*, enlarged portion of *14* showing wall structure. *13,16,19,20* are from bed 281; *12,15* are from bed 272; and *14,17,21* are from bed 270.

22–24—Triticites sp. A. *22,23*, Axial sections, Univ. Ill. nos. ×1412b, ×1412; and *24*, tangential section, Univ. Ill. no. ×1412a. All from bed 289.

25–27—Triticites cf. *T. beedei* Dunbar & Condra. *25,27*, Axial sections, Univ. Ill. nos. ×1413a, ×1413; and *26*, sagittal section, Univ. Ill. no. ×1413c. All from bed 293.

28–32—Triticites cf. *T. confertus* Thompson. *28–30*, Axial sections, Univ. Ill. nos. ×1414e, 1414f, ×1414d; and *31–32*, sagittal sections, Univ. Ill. nos. ×1414b, ×1414h. *29,30,32* are from bed 129A; and *28,31* are from bed 132A.



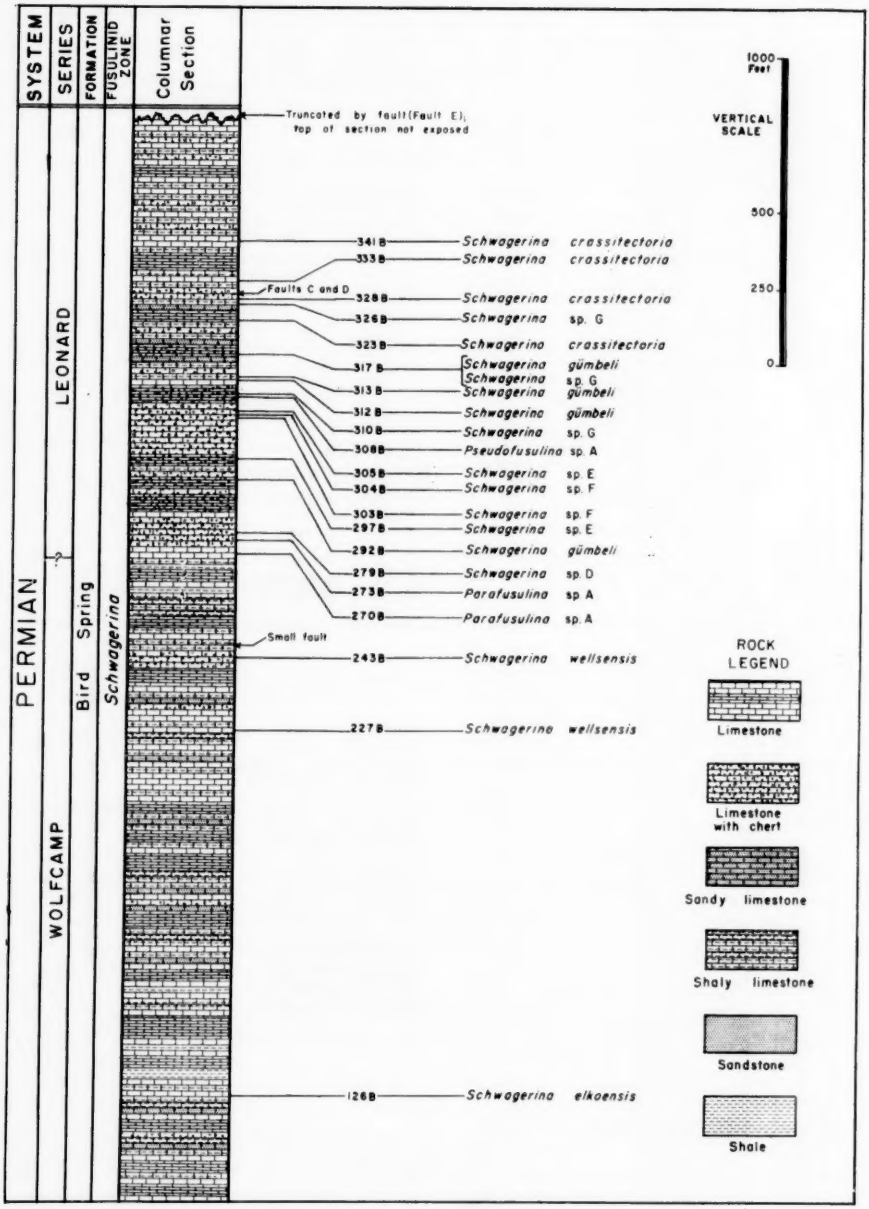
TEXT-FIG. 2—Map showing course of section in Lee Canyon area.

tween Mississippian and Pennsylvanian occurs within this interval. Megafossils collected from some of those beds were sent to William H. Easton who made the following identifications and age determinations:

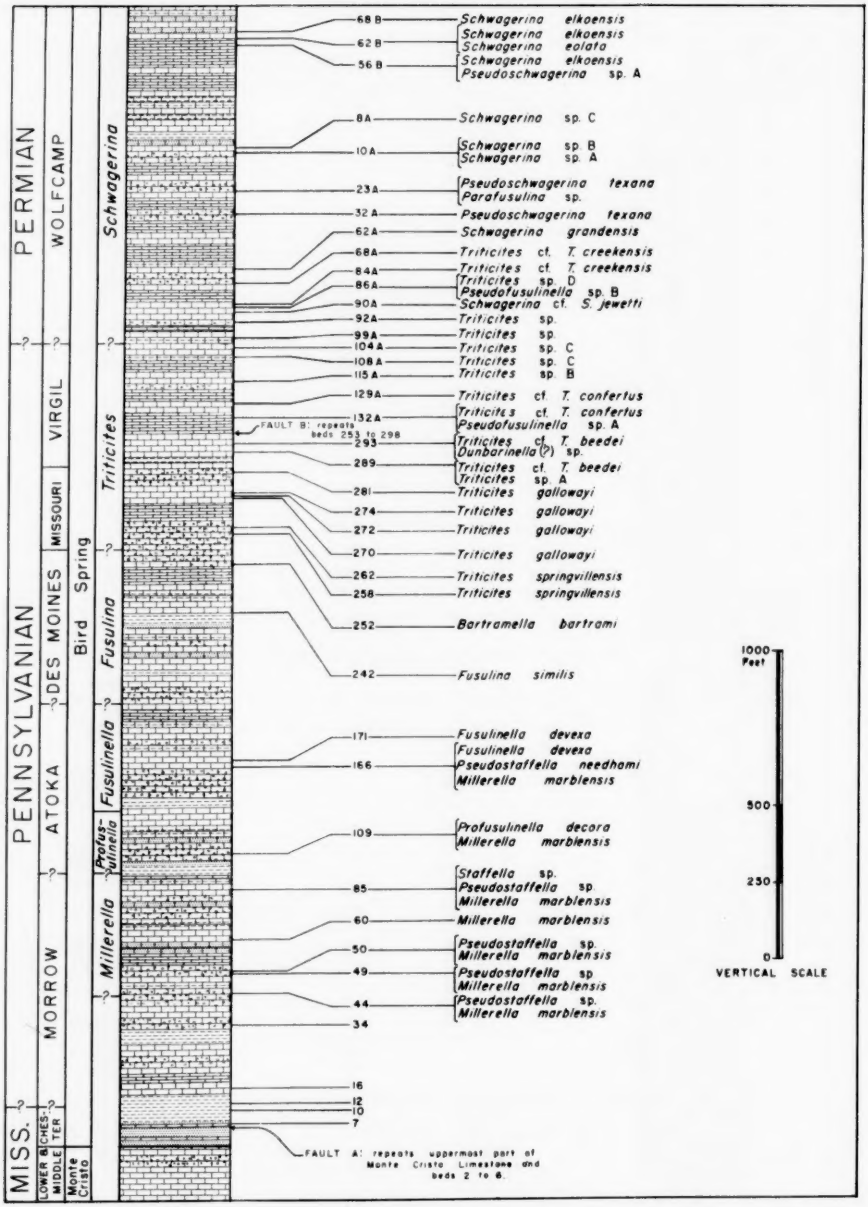
Bed 7: 64 feet above the base of the Bird Spring formation. Late Mississippian, Chesterian.

Linoproductus cf. *L. ovatus*
Productus parvus
Dictyoclostus aff. *D. inflatus*
Spirifer n. sp. (near *S. pellaensis*)
Martinia? sp.
Eumetria costata

Bed 10: 113 feet above the base of the Bird Spring formation. Chesterian or Morrowan.



TEXT-FIG. 3—Generalized columnar section of the upper half of the Bird Spring formation showing stratigraphic distribution of fusulinids. Fusulinids from bed 341B down to bed 1B identified by Christy (1958).



TEXT-FIG. 4—Generalized columnar section of the lower half of the Bird Spring formation showing stratigraphic distribution of fusulinids. Names of megafossils from beds 7 to 34 listed in text. For explanation of rock legend see Text-fig. 3.

Antiquatonia or *Dictyoclostus* sp.

Bed 12: 130 feet above the base of the Bird Spring formation. Chesterian or Morrowan.

Antiquatonia aff. *A. morrowensis* or *Dictyoclostus inflatus*
Spirifer sp.

Bed 16: 180 feet above the base of the Bird Spring formation. Probably Early Pennsylvanian, Morrowan.

Amplexus sp.
Triplophyllites sp.
Antiquatonia n. sp. (resembles *Marginifera muricatina*)
productid unidentified
Spirifer? sp.
Composita ovata
gastropod unidentified

Bed 34: 385 feet above the base of the Bird Spring formation. Early Pennsylvanian, Morrowan.

Derbyia sp.
Antiquatonia n. sp. (resembles *Marginifera muricatina* in ornamentation and size; very common)
possibly new genus of productid near *Juresania*
Spirifer opimus
Spirifer cf. *S. occidentalis*
Spirifer n. sp. (possibly new genus with strong ornamentation near periphery)
Composita ovata
Composita deflecta
Hustedia miseri
Hustedia cf. *H. brentwoodensis*

Thus the lower 515 feet of the Bird Spring formation are Late Mississippian (Chesterian) and Early Pennsylvanian (Morrowan), with no distinct lithologic or faunal breaks between the two systems. Inasmuch as bed 7 is Late Mississippian and bed 34 is Early Pennsylvanian, the transitional boundary lies between them with the probability that it lies in the interval between beds 7 and 16 (see Text-fig. 4). No attempt is made here to establish a definite time boundary.

This lower 515 foot interval (lower part of the Indian Springs member described by Longwell & Dunbar, 1936) occupies a stratigraphic position equivalent, in part at least, to the Manning Canyon shale in Utah (Gilluly, 1932; Nolan, 1935; Baker, 1947; Baker et al., 1949), to the upper part of the Tonka formation of the Elko area, Nevada (Dott, 1955), and to the higher beds in the Diamond Peak formation in the Diamond Range, Nevada (Dott, 1955). It is probably the age equivalent of beds in the basal Ely limestone in the Eureka vicinity (Nolan, Merriam, & Williams, 1956) and Pioche area, Nevada (Westgate & Knopf, 1932). Dott raised the Ely limestone to group status in the Elko-Eureka region and extended the unit from the type area to Pioche, Nevada, and the Confusion Range, Utah. He supported the view of Easton et al. (1953) by rejecting the term Bailey Springs limestone for the Pioche district in favor of the name of the better defined Ely limestone. In the Confusion Range, the Mississippian-Pennsylvanian transition occurs in the lowermost beds of the Ely limestone (Hose & Repenning, 1959). In the Elko vicinity and the Diamond Range, Dott subdivided the Ely limestone into two formations which in ascending order are the Moleen and Tomera. He indicated that the uppermost parts of the Tonka, Diamond Peak, Chainman shale (in Utah), and the basal Moleen and Ely formations are probably equivalents and are the lowermost Pennsylvanian (Springeran) age. Bissell (1960) included Mississippian-Pennsylvanian transitional beds at the base of the Ely and Bird Spring formations in east-central and southern Nevada and western Utah into the newly designated Illipah formation. The reader is referred to Bissell's article for further details regarding this and other correlations not mentioned in this paper. Apparently the Rest Spring shale overlying the Perdido in the Quartz Spring area and Ubehebe Peak Quadrangle, California, which was considered by McAllister (1952, 1955) to be Early Pennsylvanian was included into the Chainman shale of Mississippian age by Merriam & Hall (1957) in the southern Inyo Mountains. They rejected McAllister's stratigraphic terms for Pennsylvanian and Permian rocks in the southern Inyos in favor of their newly defined units.

Fusulinids are abundant throughout the remaining part of the Bird Spring formation. They have proved to be excellent indices for zonation and correlation of time-stratigraphic units over wide areas. In the Pennsylvanian of North America five major fusulinid zones, based on restricted

range or dominance of genera, have been defined (Thompson, 1948). These are in ascending order: Zone of *Millerella*, Zone of *Profusulinella*, Zone of *Fusulinella*, Zone of *Fusulina*, and Zone of *Triticites*. The Zone of *Pseudoschwagerina* and Zone of *Parafusulina*, respectively, define the Wolfcampian and Leonardian of the Permian. Only in the Zones of *Profusulinella*, *Fusulina*, and *Pseudoschwagerina* are the genera restricted to the zones bearing their names. Inasmuch as the upper part of the Bird Spring formation is so dominated by *Schwagerina*, it seems more appropriate here to consider that interval as the Zone of *Schwagerina*. *Pseudoschwagerina* and *Parafusulina* are present in the section but are not useful for zonation because of their limited vertical distribution.

Zone of Millerella.—*Millerella* is found in North America in rocks ranging from Late Mississippian to Late Pennsylvanian. Inasmuch as it is the dominant fusulinid genus in Morrowan rocks, this part of the Pennsylvanian is termed the Zone of *Millerella* (Thompson, 1944, 1945, 1948).

Forms referable to *Millerella marblensis* Thompson are present in the 700 foot interval beginning 515 feet above the base of the Bird Spring formation. This species dominates the fusulinid fauna in the lower 300 feet of this interval where it is associated with less abundant *Staffella* and *Pseudostaffella*. These latter forms generally indicate Atokan or younger age; however, their occurrence below typical early Atokan forms indicates that they may be older. Therefore, the lower 300 feet of the *Millerella*-bearing rocks are tentatively correlated with the upper Morrow series. It is realized that they might be, in part at least, correlative with the lower Atokan. Thompson & Zeller (1956) also found the association of *Staffella* and *Millerella* in rocks of western Utah which they questionably referred to the late Morrowan.

The *Millerella*-bearing Morrowan beds in the Bird Spring formation are correlative with the lower part of the Moleen formation of Nevada and the Ely limestone of Nevada and Utah (Ogden, 1951; Dott, 1955; Hose & Repenning, 1959). They may, in part at least, be equivalent to the basal Wells formation of Idaho and Utah (Mansfield, 1927; Williams & Yolton, 1945) and Oquirrh formation of Utah (Gilluly, 1932; Nolan, 1935; Baker, 1947; Baker et al., 1949). Rocks of probable Early Pennsylvanian age are present in the eastern Sierra Nevada, California (Rinehart et al., 1959).

Zone of Profusulinella.—The genus *Profusulinella* is restricted to Derryan (Atokan) age rocks and occurs below primitive *Fusulinella* faunas (Thompson & Zeller, 1956). Its short stratigraphic range and occurrence in several areas makes this genus highly useful for correlation purposes.

One member of the genus *Profusulinella*, *Profusulinella decora* Thompson, is present in bed 109, about 940 feet above the base of the Bird Spring formation. It is associated with *Millerella marblensis*. *Profusulinella decora* characterizes a zone in the upper part of the Green Canyon group in Powwow Canyon, western Texas.

Thompson & Zeller (1956) found *Profusulinella* in limestones of the Confusion Range in western Utah, and Dott (1955), working in eastern Nevada, reported the genus to be widespread in the upper Moleen formation and lower Ely limestone. Henbest (in Hose & Repenning, 1959) reported *Profusulinella?* from the Ely limestone in the Confusion Range. It also occurs in the widespread Green Canyon group in New Mexico (Thompson, 1942, 1948). Lower Atokan strata may also be present in the lower part of the Oquirrh formation in Utah, the Wells formation in Idaho, and the Horquilla limestone (lower Naco group), southeastern Arizona (Gilluly, Cooper, & Williams, 1954).

Zone of Fusulinella.—The genus *Fusulinella* first appears in rocks of middle Derryan (Atokan) age and ranges into the Desmoinesian (Thompson, 1945). It is the dominant fusulinid form in late Derryan (Atokan) and early Desmoinesian rocks of the United States, and this part of the Pennsylvanian is defined as the Zone of *Fusulinella*. A species of *Fusulinella*, *Fusulinella devexa* Thompson, is present in beds 166 and 171, 1220 feet and 1240 feet, respectively, above the base of the Bird Spring formation, where it is associated with *Pseudostaffella needhami* Thompson and *Millerella marblensis*. *Fusulinella devexa*

characterizes a zone in the Cuchillo Negro formation of Atokan age in southern New Mexico where it is also associated with *Pseudostaffella needhami* and *Millerella marblensis* (Thompson, 1948). Lying 30 and 140 feet stratigraphically below *Fusulinella devexa* in the Bird Spring formation are beds containing *Chaetetes* which Dott (1954, 1955) also found associated with *Profusulinella* and *Fusulinella* in eastern Nevada. Although *Chaetetes* is generally found in rocks of Desmoinesian age in the Midcontinent, he considered it to be characteristic mainly of Atokan age in the central Great Basin because of its fusulinid associations. Additional evidence for this conclusion is therefore shown by the present study.

The interval containing *Fusulinella* in the Bird Spring formation is considered here to be late Atokan in age and is correlated with corresponding zones of the same age in the Wells formation of Idaho, Oquirrh formation of Utah, Ely limestone of Nevada and Utah, upper Moleen and part of the Tomera formations of Nevada, the lower part of the Keeler Canyon formation in the southern Inyo Mountains, California (Merriam & Hall, 1957), and the lower Horquilla limestone of the Naco Group, southeastern Arizona. Inasmuch as the Battle formation of northwest Nevada contains *Chaetetes* and *Ozawainella*, Henbest (*in* Roberts, 1951) reported it to be Desmoinesian; however, Dott (1955) considered the upper part of the Battle formation to be equivalent to parts of the Moleen and Tomera formations which he indicated were Atokan. Approximately 1100 feet of Pennsylvanian rocks in the Nopah Range, California, were assigned by Hazzard (1954) to the Bird Spring formation. Two members were differentiated, a lower more clastic one, 100+ feet thick, of probable Lampasas age, and an upper one of Desmoinesian age. Derryan (Atokan) rocks are widespread in New Mexico (Needham, 1937; Thompson, 1942).

Zone of Fusulina.—With the exception of one possible occurrence in late Atokan rocks, *Fusulina* is considered to be restricted to the Desmoinesian which is defined as the Zone of *Fusulina*. *Fusulina similis* Galloway & White is present in bed 242, 1730 feet above the base of the Bird Spring formation and occurs 130 feet below *Bartramella bartrami* Verville, Thompson & Lokke. The latter species was discovered in rocks of late Desmoinesian age belonging to the Ely limestone of east-central Nevada (Verville, Thompson & Lokke, 1956). This close stratigraphic relationship between the two species indicates that the interval in which they occur is to be correlated with the upper part of the Des Moines series of Iowa and that the Atokan-Desmoinesian contact in the Bird Spring lies somewhere between beds 242 and the highest occurrence of *Fusulinella devexa* (bed 171). It should be pointed out that the only known occurrence of *Bartramella bartrami* is in the Ely limestone and that the range of the species is not fully understood. The only other species of *Bartramella* is reported from rocks of Wolfcampian age in Idaho (Thompson, Dodge & Youngquist, 1958).

The Desmoinesian portion of the Bird Spring formation is the correlative, in part at least, with beds in the Wood River (Bostwick, 1955), Wells (Mansfield, 1927; Williams & Yolton, 1945), and Oquirrh (Baker, 1947; Baker et al., 1949; Thompson et al., 1950) formations. In eastern Nevada *Fusulina*-bearing beds were found in the upper Ely limestone of the Cherry Creek Range (Dott, 1955; Thompson et al., 1956) and in the upper Tomera formation of the Ely group (Dott, 1955). Pennsylvanian strata younger than Atokan in the Ely limestone are not present in either the Confusion Range, Utah (Kraetsch & Jones, 1951; Hose & Repenning, 1959), or the Eureka area, Nevada (Nolan, Merriam & Williams, 1956). Dott (1955) noted the absence or paucity of *Fusulina* zones in several places in the Great Basin region. As aforementioned, Henbest (*in* Roberts, 1951) considered the Battle formation of north-central Nevada to be Desmoinesian, but Dott (1955) considered it to be Atokan in age. Kirk's (1918) identification of *Fusulina* in the "Basal Pennsylvanian limestones" in the Inyo Range, California, was probably incorrect because Merriam & Hall (1957), in restudying the late Paleozoic section there, did not report the genus from the newly named Keeler Canyon formation which was defined to include the former "Basal Pennsylvanian limestones." As aforementioned, Hazzard (1954) assigned the

upper 1000 feet of the Bird Spring formation in the Nopah Range, California, to the Des Moines series and noted that those beds were the latest Paleozoic rocks represented in that area. Strata containing a Desmoinesian fauna are present in the Horquilla limestone (Naco group) in southeastern Arizona (Gilluly et al., 1954) and are widespread in New Mexico (Needham, 1937; Thompson, 1942).

Zone of Triticites.—The genus *Triticites* dominates the fusulinid faunas in Missourian and Virgilian rocks of North America so that part of the Pennsylvanian is defined as the Zone of *Triticites* (Thompson, 1945, 1948). The genus first appears near the base of the Missouri series, and its range extends into the Wolfcamp.

In the Bird Spring formation the Zone of *Triticites* appears a short distance above the beds containing *Bartramella bartrami* and *Fusulina similis*. This zone contains *Triticites springvillensis* Thompson, Verville & Bissell, *T. gallowayi* Needham, *T.* cf. *T. beedei* Dunbar & Condra, *Dunbarinella?* sp., *Pseudofusulinella* sp. A, *T.* cf. *T. confertus* Thompson, and several other unidentified species of *Triticites*.

The oldest representative is *Triticites springvillensis* which occurs in beds 258 and 262, 1975 feet and 2000 feet, respectively, above the base of the Bird Spring formation. This form is closely related to the group of *T. irregularis* which is so characteristic of the Missouri series of the Midcontinent and the Canyon series of Texas. Thus, the interval containing this species is Missourian in age and probably is to be correlated with the Kansas City group and equivalent age beds in the Canyon series. *Triticites gallowayi* is a member of a group of *Triticites* occurring immediately below the subzone of *Triticites ventricosus* in New Mexico (Needham, 1937). It is so closely similar to species of *Triticites* characteristic of late Missourian and early Virgilian age in North America that the interval in which it occurs in the Bird Spring formation was most probably deposited during that time. The Missouri-Virgil boundary is here tentatively placed above the highest bed containing *T. gallowayi* although it is realized that the interval in which it is found may, all or in part, belong to the Virgil series. Strata of equivalent age are present in the Oquirrh formation of Utah (Baker, 1947; Baker et al., 1949; Thompson et al., 1950), lower Strathearn formation in the Elko area, Nevada (Dott, 1955), and probably in the Wood River, Wells, and middle Keeler Canyon formations. The apparent lack of Missourian and Virgilian beds in contrast

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EXPLANATION OF PLATE 145

All figures ×10.5

FIGS. *1–3*—*Triticites* cf. *T. confertus* Thompson. *1*, Axial section, Univ. Ill. no. ×1414; *2*, sagittal section, Univ. Ill. no. ×1414g, and *3*, tangential section, Univ. Ill. no. ×1414a. *1* is from bed 129A; and *2,3* are from bed 132A.

4–6—*Triticites* sp. B. *4,5*, Axial sections, Univ. Ill. nos. ×1415, ×1415a; and *6*, sagittal section, Univ. Ill. no. ×1415b. All from bed 115A.

7–9—*Triticites* sp. C. *7*, Axial section, Univ. Ill. no. ×1416; and *8,9*, sagittal sections, Univ. Ill. nos. ×1416b, ×1416a. *9*, is from bed 108A; and 7,8 are from bed 104A.

10–12—*Triticites* spp. *10*, Axial section; *11*, tangential section; *12*, sagittal section; Univ. Ill. nos. ×1417, 1417a, ×1417b. All from bed 99A.

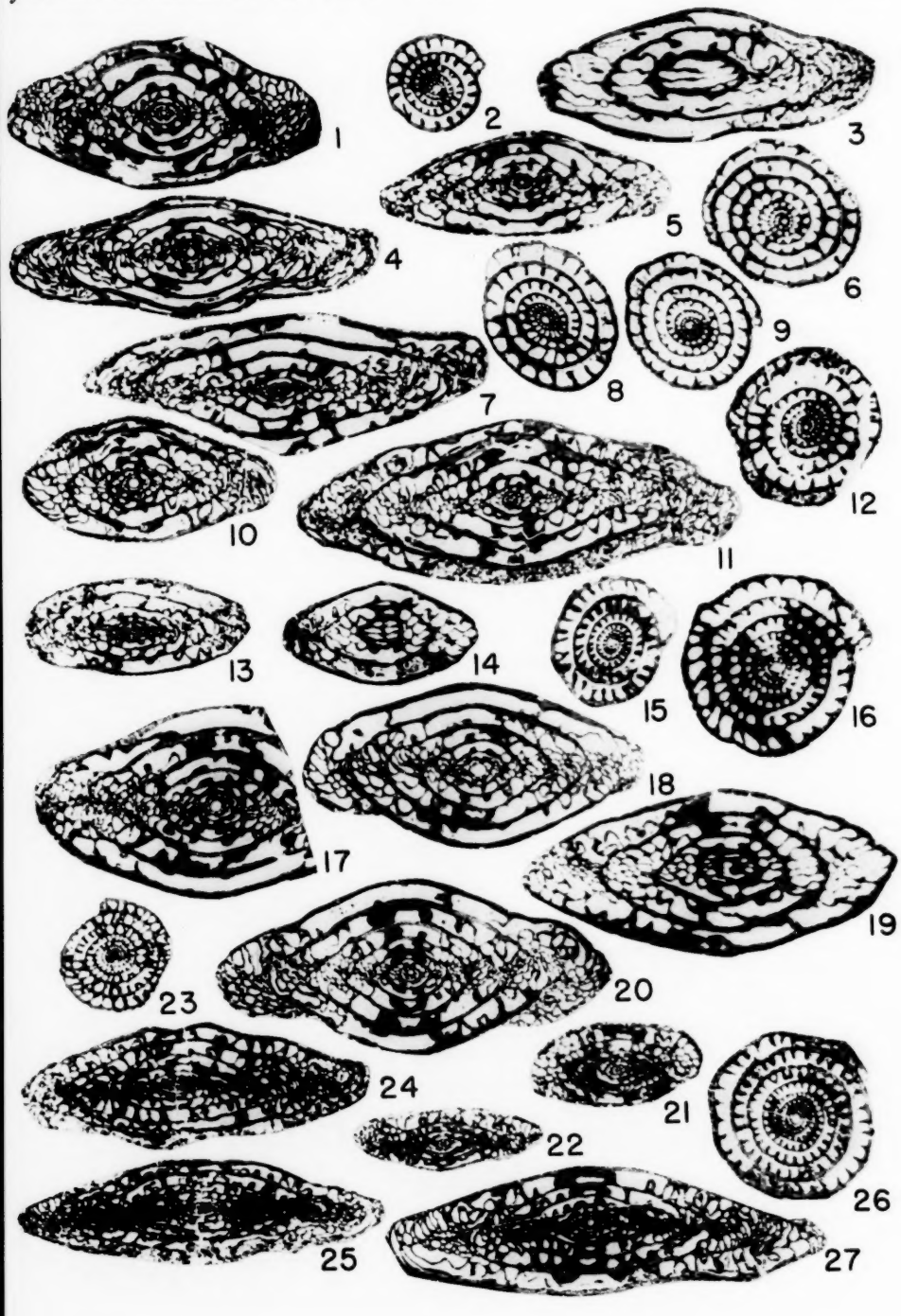
13–15—*Triticites* sp. D. *13*, Axial section, Univ. Ill. no. ×1418; *14*, tangential section, Univ. Ill. no. ×1418a; and *15*, sagittal section, Univ. Ill. no. ×1418b. All from bed 86A.

16–20—*Triticites* cf. *T. creekensis* Thompson. *16*, Sagittal section, Univ. Ill. no. ×1419d; *17,18,20*, axial sections, Univ. Ill. nos. ×1419, ×1419a, ×1419b. *19*, tangential section, Univ. Ill. no. ×1419e. *18,20* are from bed 84A; and *16,17,19* are from bed 68A.

21,22—*Dunbarinella?* sp. *21*, Axial section; and *22*, tangential section; Univ. Ill. nos. ×1420, ×1420a. Both from bed 293.

23–25—*Schwagerina* cf. *S. jewetti* Thompson. *23*, Sagittal section, Univ. Ill. no. ×1421a; and *24,25*, axial sections, Univ. Ill. nos. ×1421c, ×1421. All from bed 90A.

26,27—*Schwagerina grandensis* Thompson. *26*, Sagittal section, hypotype, Univ. Ill. no. ×1422a; and *27*, axial section, hypotype, Univ. Ill. no. ×1422c. Both from bed 62A.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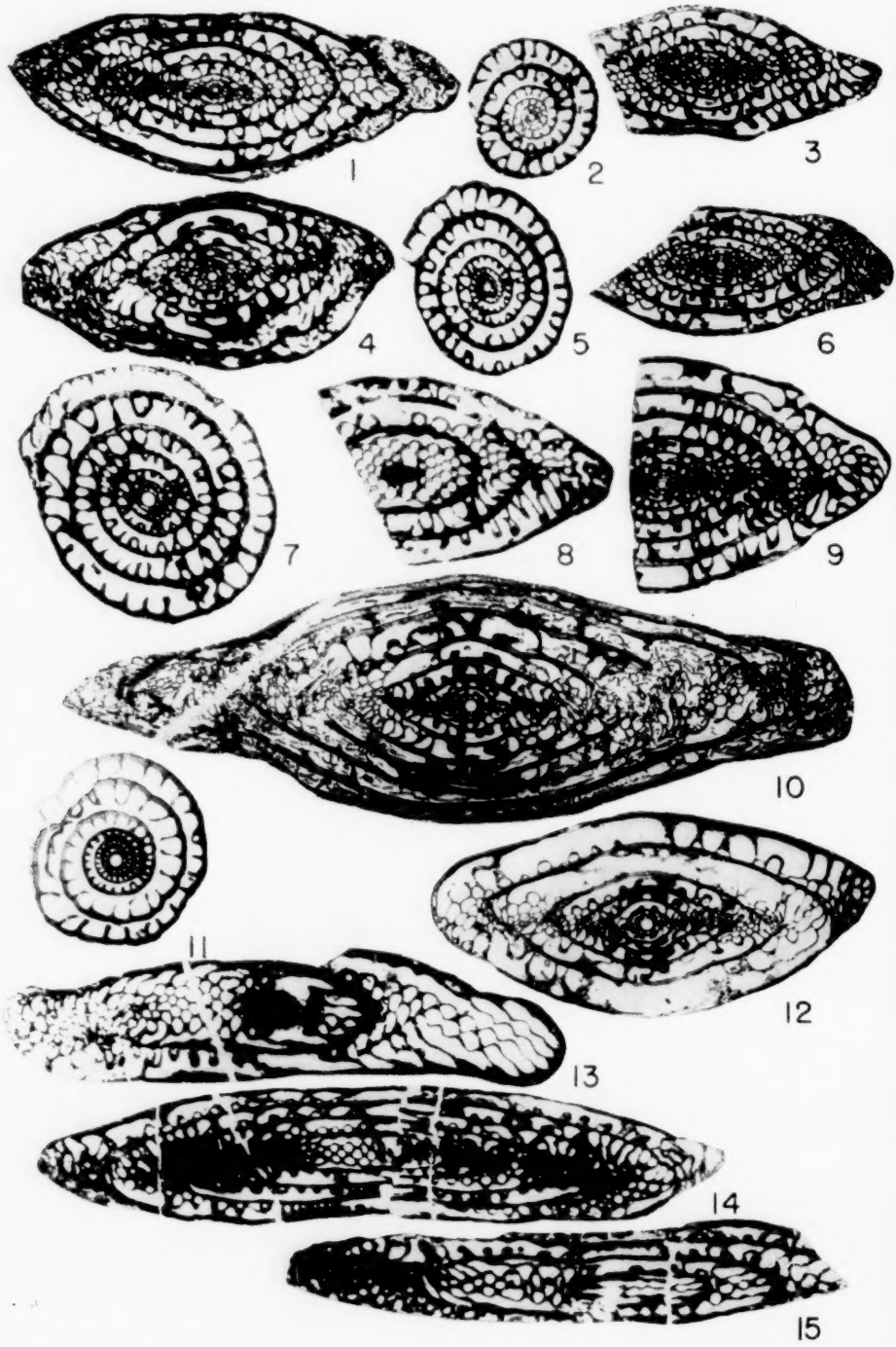
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with widespread older Pennsylvanian and Permian rocks in the eastern Nevada region has been established (Dott, 1955). The lower Callville limestone may be, in part at least, of Missourian age (McNair, 1951). Rocks of that age are widespread in New Mexico (Thompson, 1942) and are present in the upper portion of the Horquilla limestone (Naco group) of southeastern Arizona (Gilluly et al., 1954).

It is concluded here that the remaining part of the Zone of *Triticites* extends from the Virgil into the Wolfcamp. There is no distinct lithologic or faunal break between the Pennsylvanian and Permian, and it appears that a gradational boundary exists between the two systems. Species similar to late Pennsylvanian forms in other areas are *Triticites* cf. *T. beedei*, *T.* sp. *A.* and *Dunbarinella?* sp. These forms are associated in beds 289 and 293 and indicate that the interval in which they occur is probably correlative with the upper Virgil series of the midcontinent. The sequence including beds 132A to 92A contains *Pseudofusulinella* sp. A and a group of forms that the author believes correspond to species of *Triticites* that Thompson (1954) considered to be ". . . undescribed representatives of *Triticites* in Virgilian rocks of Kansas and Texas and several in the Permian of Texas and Kansas." *Pseudofusulinella* has mostly been found in Permian rocks of western North America but has been observed in rocks correlated with the Virgil series (Thompson, Dodge & Youngquist, 1958). The fact that a seemingly advanced form of *Schwagerina*, *S.* cf. *S. jewetti* Thompson, appears abruptly above the interval dominated by *Triticites* indicates that Wolfcampian time was already well in progress when the rocks containing that species of *Schwagerina* were deposited. Thus, it appears that the transitional Pennsylvanian-Permian boundary lies between beds 132A and 90A. For convenience, the base of the Permian is here questionably and tentatively placed a short distance below the first occurrence of *Schwagerina* (bed 90A). However, it is realized that all or part of the underlying 340 foot interval between beds 132A and 90A may be correlative with the Wolfcamp. The strata here correlated with the Virgil series occupy a stratigraphic position equivalent to parts of the Wood River, Wells, Oquirrh, Strathearn, and middle Keeler Canyon formations. The Antler Peak limestone in north-central Nevada is late Pennsylvanian (Roberts, 1951) as well as the lower Earp (lower Naco group) in southeastern Arizona (Gilluly, Cooper & Williams, 1954). Fusulinids of that age are present in rocks of the Sublett Range, Idaho (Thompson et al., 1958), and in the Callville limestone of northwest Arizona (McNair, 1951). The upper part of the latter formation grades laterally eastward into siltstones and sandstones of the lower Supai formation in northwest Arizona (McNair, 1951; Brill, 1959). Beds of Virgilian age are widely distributed in New Mexico (Needham, 1937; Thompson, 1942).

Zone of Schwagerina.—Fusulinids from the lower part of this zone in the Bird Spring formation have been studied by the writer. Those collected from the upper 3800 feet were given to Christy who described

EXPLANATION OF PLATE 146

All figures ×10.5

FIGS. *1–3,6—Schwagerina* sp. A. *1–3,6*, Axial sections, Univ. Ill. nos. ×1423, ×1423d, ×1423c; and *2*, sagittal section, Univ. Ill. no. ×1423a. All from bed 10A.

4—Schwagerina sp. B. Axial section, Univ. Ill. no. ×1424. From bed 10A.

5,7–9—Schwagerina sp. C. *5,7*, Sagittal sections, Univ. Ill. nos. ×1425a, ×1425b; *8*, tangential section, Univ. Ill. no. ×1425c; and *9*, axial section, Univ. Ill. no. ×1425. All from bed 8A.

10–12—Pseudoschwagerina texana Dunbar & Skinner. *10,12*, Axial sections, hypotypes, Univ. Ill. no. ×1426, ×1426a; and *11*, sagittal section, hypotype, Univ. Ill. no. ×1426b. *11,12* are from bed 23A; and *10* is from bed 32A.

13–15—Parafusulina sp. *13,15*, Tangential sections, and *14*, axial section; Univ. Ill. nos. ×1427a, ×1427b, ×1427. All from bed 23A.

them and determined the Wolfcamp-Leonard boundary. The lower part of the zone contains: *Schwagerina* cf. *S. Jewetti* Thompson, *Triticites* cf. *T. creekensis* Thompson, *Pseudofusulinella* sp. B, *Schwagerina grandensis* Thompson, *Pseudoschwagerina texana* Dunbar & Skinner, an undetermined species of *Parafusulina*, and several undetermined species of *Schwagerina*. The upper part of the zone. studied by Christy (1958) carries a species of *Pseudoschwagerina*, *Schwagerina elkoensis* Thompson & Hansen, *S. eolata* Thompson, *S. wellsensis* Thompson & Hansen, a species of *Parafusulina*, *S. gumbeli* Dunbar & Skinner, a species of *Pseudofusulina*, *S. crassitectoria* Dunbar & Skinner, and several undetermined species of *Schwagerina*. The forms identified by Christy are listed on the diagrams of the stratigraphic section of the Bird Spring formation (Text-figs. 3 and 4).

As aforementioned, the Pennsylvanian-Permian boundary is not far below the first occurrence of *Schwagerina*. With reference to the Wolfcamp-Leonard boundary, the present report agrees with the findings of Christy who placed the boundary between the highest occurrence of *Schwagerina wellsensis* and the lowest occurrence of *S. gumbeli*. The former species was described from Wolfcampian age rocks in Nevada (Thompson, 1954), and the latter characterizes a zone about 450 feet above the base of the Leonard formation of Texas (Dunbar & Skinner, 1937). Christy questionably placed the boundary below the occurrence of a large form of *Parafusulina* occurring between *S. wellsensis* and *S. gumbeli*. This procedure is followed in the present report.

Another species of *Parafusulina* appears much lower in the section where it is associated with *Pseudoschwagerina texana*. It is a primitive form of the genus, and it occurs with typical Wolfcampian fusulinids. Thus the range of *Parafusulina* seems to extend well below the base of the Leonard. In fashion similar with the Lee Canyon area of southern Nevada, fusulinid-bearing Wolfcampian beds lie without stratigraphic break above upper Pennsylvanian rocks in southern Idaho (Bostwick, 1955; Youngquist & Haegele, 1955; Thompson et al. 1958), in the Oquirrh formation of Utah (Nolan, 1935; Baker, 1947; Thompson et al., 1950; Thompson, 1954), in the Strathearn formation of northeast Nevada (Dott, 1955); in the Keeler Canyon formation in the Inyo Range, California (Merriam & Hall, 1957), and in the Earp formation (Naco group) of southeastern Arizona (Gilluly et al. 1954; Thompson, 1954). Transitional intervals may also occur in the Antler Peak limestone and Pumpernickel formation in north-central Nevada (Roberts, 1951). Fusulinid-bearing Wolfcampian strata that overlie older rocks unconformably are present in the upper Ely limestone of the Confusion Range, Utah (Hose & Repenning, 1959; Thompson, 1954), in siltstones and limestones in the Diamond Range, Nevada (Dott, 1955), in the Carbon Ridge and Garden Valley formations of the Eureka District, Nevada (Dott, 1955; Nolan et al., 1956), in the Bird Spring formation in the Providence Mountains, southern California (Thompson & Hazzard, 1946), and in the McCloud limestone in northern California (Thompson & Wheeler, 1946). Fusulinds representative of Early Permian age are also present in the lower Owens Valley formation in the Inyo Mountains, California (Merriam & Hall, 1957), and in the Pakoon limestone of northwest Arizona (McNair, 1951). The Havallah formation of north-central Nevada (Roberts, 1951) and the Colina limestone (middle Naco group) of southeastern Arizona (Gilluly et al., 1954) are predominantly Wolfcampian in age. Mackenzie (Rinehart et al., 1959) identified fossils of questionable Permian age in hornfels from the eastern Sierra Nevada, California. In the Elko region, Nevada, Dott (1955) indicated that fossiliferous strata above the Strathearn formation are mostly Wolfcampian, but probably include beds as young as Leonardian and even Guadalupian.

After this paper was written, Fails (1960) subdivided the Paleozoic strata, mostly siltstones and limestone, above the Strathearn at Carlin Canyon west of Elko into three formations which, in ascending order, are: the Buck Mountain (Wolfcampian), Beacon Flat (Wolfcampian-Leonardian), and the Carlin Canyon (Leonardian and possibly Guadalupian).

Fusulinid faunas indicative of Leonardian age and containing elements similar to the

upper Bird Spring formation have been identified in the Arcturus formation west of Ely, Nevada (Knight, 1956), in the Carbon Ridge formation of the Eureka District (Nolan et al., 1956), and in the Owens Valley formation in the Inyo Mountains (Merriam & Hall, 1957). Other rocks probably correlative, in part at least, with the upper Bird Spring are in the Garden Valley formation of the Eureka District and the McCloud limestone, northern California.

As aforementioned, the top of the section of the Bird Spring formation north of Lee Canyon is truncated by faulting (Text-figs. 2 and 3). *Schwagerina crassitectoria* is in the uppermost fusulinid-bearing bed, 350 feet from the top of the stratigraphic succession. Age of the uppermost strata above the fusulinid zone is not known, and so correlation in this report with the Leonard series is tentative. It is possible that uppermost portions of the Bird Spring formation may, in part at least, have been deposited during early Guadalupian time.

CONDITIONS OF DEPOSITION

Prevalence of arenaceous and silty beds in the lowermost Bird Spring and alternations of clastic limestones which are locally cross-bedded with siltstones in the upper part indicate periods of shallow water, above wave base, during deposition of the formation. Reworking of material was concomitant with those conditions. Low percentage of clastic limestones and lack of evidence of great reworking in several beds attest to intermittent periods of greater depth and less agitation. In his study of Pennsylvanian rocks in northeastern Nevada, Dott (1958) also observed the cyclic nature of limestone deposition. In a discussion of Pennsylvanian sedimentation in the southwestern United States, Wanless & Patterson (1951) noted that although much of the region was almost continuously covered by shallow water, the sea bottom fluctuated above and below wave base, giving rise to cyclical marine deposits showing alternations of agitated and non-agitated sediments. According to their hypothesis, sea level changes were eustatic, perhaps worldwide in extent, and gave rise to the cyclical sedimentation in the central and eastern United States described by many workers such as Weller (1930, 1931), Wanless & Weller (1932), Wanless & Shepard (1936), Wanless (1939, 1955) and Moore (1931, 1936).

The great thickness of the Bird Spring formation indicates prolonged subsidence and marine deposition spanning two systemic boundaries. Earliest beds were deposited along the eastern margin of a trough whose locus of maximum subsidence probably shifted eastward during sedimentation. During Late Mississippian and Pennsylvanian about 2600 feet of predominantly carbonate beds accumulated in what is now the Lee Canyon region and 4500 feet were deposited during the Permian. Brill (1959) discussed the influence of basins on Permo-Pennnsylvanian deposition in southeastern Nevada and western Utah.

BIRD SPRING FUSULINID COLLECTIONS

A total of 58 collections of fusulinids were studied from the section of the Bird Spring formation north of Lee Canyon. Samples from the upper part of the formation, 24 in number, were studied by Christy (1958); the remaining 34 collections from the lower half of the formation were studied by the present writer. The following is a list of beds from which the fusulinid collections for this report were obtained:

Stratigraphic height above base of formation (feet)	Bed Number	Lithology and fusulinids
515–520	44	Limestone, silty or sandy, dark-gray, weathering medium-gray and light-gray; fossiliferous, containing brachiopods, syringoporoid corals, fusulinids and horn corals. Contains gray and brown chert nodules 2 to 12 inches thick that have concentric structure. Unit weathers angular and blocky. Horn corals perceptible in large chert nodules. *Pseudostaffella* sp. and *Millerella marblensis*.
540–550	49	Limestone, medium and fine crystalline, medium to dark-gray, weathering

Stratigraphic height above base of formation (feet)	Bed Number	Lithology and fusulinids
		medium-gray; contains brown and gray chert and partly silicified limestone in irregular nodules and seams 3 to 5 inches in thickness. *Pseudostaffella* sp. and *Millerella marblensis*.
550–565	50	Limestone, massive, dark-gray, weathering gray, forming prominent ledge near ridge-top; weathered surface highly pitted and grooved; contains gray chert nodules and seams averaging 4 inches in thickness. Locally fossiliferous, containing fusulinids, horn corals, and minute shell fragments. Fusulinids in 6 inch zone near middle of unit. *Pseudostaffella* sp. and *Millerella marblensis*.
655–660	60	Limestone, dark-gray, weathering medium-gray, appears massive; weathered surface pitted and grooved; cut by many irregular thin white calcite stringers; contains fusulinids. Caps first main ridge above Monte Cristo limestone. *Millerella marblensis*.
825–826	85	Limestone, fine crystalline, black, weathering dark-gray; fossiliferous, containing bryozoa, crinoid columnals, and fusulinids. *Staffella* sp., *Pseudostaffella* sp., and *Millerella marblensis*.
937–945	109	Limestone, massive, fine and medium-crystalline, stylolitic, dark-gray, weathering dark-gray for lower four-fifths and medium-gray for top one-fifth of unit; weathered surface highly pitted and grooved; contains minor amount of gray and black chert nodules, mainly at base; contains finely fragmented fossils throughout; contains bryozoa, crinoids, brachiopods, and fusulinids. Forms prominent ledge. *Profusulinella decora* and *Millerella marblensis*.
1222–1225	166	Limestone, shaly and parts along thin planes; largely concealed; contains large horn corals and small fusulinids. *Fusulinella devexa*, *Pseudostaffella needhami*, and *Millerella marblensis*.
1243–1245	171	Limestone, crinoidal, medium-gray, weathering blue-gray; weathers red-brown in middle where there is an abundance of fossils including brachiopods and fusulinids; contains large black chert nodules at top that are up to 4 inches thick; has rough weathered surface. *Fusulinella devexa*.
1726–1728	242	Limestone, fine-crystalline, light-gray, weathering blue-gray; contains brown weathered fossiliferous portion in which are brachiopods and fusulinids; separated from bed below by fairly persistent light-gray chert band. *Fusulina similis*.
1840–1915	252	Limestone, very massive, forming prominent outcrop, light-gray, weathering light-gray and medium-gray; contains chert nodules beginning 9 to 10 feet from base, but chert is very abundant in thick seams about 12 feet from base; contains syringoporoid corals, especially in lower half; contains horn corals and fusulinids. Weathered surface is highly grooved. Unit is somewhat crinoidal in middle and upper parts. *Bartramella bartrami*.
1975–1990	258	Limestone, massive, forming ledge above long scree slope, light to medium-gray, weathering medium-gray and blue-gray; contains gray chert nodules beginning 6 feet above base; fusulinid zone 4 feet above base. *Triticites springvillensis*.
2005–2010	262	Limestone, somewhat silty, light- to medium-gray, weathering light-gray and blue-gray, containing irregular gray chert masses; contains abundant small fusulinids, especially near top. *Triticites springvillensis*.
2075–2095	270	Limestone, finely crystalline, light-gray, weathering light-gray, weathered surface severely pitted and grooved; contains irregular gray chert seams and nodules; fusulinids abundant at top. *Triticites gallowayi*.
2096–2105	272	Limestone, finely crystalline, light-gray, weathering light-gray, appearing

Stratigraphic height above base of formation (feet)	Bed Number	Lithology and fusulinids
		sugary on weathered surface; contains small amount of scattered light-gray and white chert; weathered surface highly grooved and pitted; contains large horn corals, large brachiopods and fusulinids. *Triticites gallowayi.*
2109–2110	274	Limestone, finely crystalline, black, weathering dark-gray to black, slightly silty, surface locally weathered to brown; contains irregular masses of gray chert; weathered surface grooved; contains spiriferoid brachiopods and fusulinids; largely concealed. *Triticites gallowayi.*
2175–2200	281	Limestone, finely crystalline, medium- to dark-gray, weathering medium-gray and dark-gray; very massive and forms prominent ledge; weathered surface pitted and grooved; locally contains chert nodules; contains fusulinids at base. *Triticites gallowayi.*
2240–2250	289	Limestone, medium-gray, weathering light-gray and buff; contains small gray chert nodules 1 to 4 inches in diameter; weathered surface smooth though deeply grooved; contains abundant scattered fusulinids and large corals; fairly massive though covered by much scree. *Triticites* cf. *T. beedei, Triticites* sp. A.
2265–2280	293	Limestone, massive, partly silty, medium-gray, weathering light-gray and blue-gray; contains fusulinids in middle; weathered surface highly grooved; highly jointed; contains scattered small gray chert nodules. *Triticites* cf. *T. beedei* and *Dunbarinella?* sp.
2350–2355	132A	Limestone, fine crystalline, dark-gray, weathering medium-gray; contains white nodular masses of calcite that weather brown; contains abundant fusulinids. *Triticites* cf. *T. confertus* and *Pseudofusulinella* sp. A.
2395–2410	129A	Limestone, fine crystalline, very massive, forming large ledge; contains abundant fusulinids in top half; weathered surface severely grooved and somewhat pitted; slightly brecciated and cut by a large amount of white calcite. *Triticites* cf. *T. confertus.*
2470–2500	115A	Limestone, massive, medium-gray, weathering light-gray at top and light blue-gray in lower half; forms prominent ledge; weathers into angular fragments and blocks; contains porous gray chert nodules, especially in lower half; somewhat silty at base; syringoporoid coral zone about 14 feet from top; fusulinids scattered throughout and are locally abundant. *Triticites* sp. B.
2545–2560	108A	Limestone, medium to dark-gray, weathering medium-gray in top half and blue-gray and buff in bottom half. Top half is non-silty and fine crystalline; bottom half shows alternation of silty and non-silty layers. Unit forms thick ledge; top half contains scattered white nodular masses of calcite that enclose chert. Contains crinoid fragments, bryozoa, and fusulinids. *Triticites* sp. C.
2580–2585	104A	Limestone, very silty, dark-gray to dark-brown, weathering buff; contains horn corals and abundant fusulinids; also contains syringoporoid corals; highly jointed; weathered surface is highly grooved. *Triticites* sp. C.
2610–2615	99A	Limestone, very silty, medium-gray, weathering buff; contains scattered fusulinids, especially near base; highly jointed and breaks into angular blocks. *Triticites* sp.
2655–2675	92A	Limestone, medium to dark-gray, weathering medium-gray in upper half and dark blue-gray in lower half where the unit becomes silty; crinoidal in lower half; contains oval gray chert nodules with concentric structure that are present mainly in top half; horn coral zone 3 feet from top, and locally the coral calices are silicified; fusulinids scattered throughout; forms 12 foot ledge. *Triticites* sp.

Stratigraphic height above base of formation (feet)	Bed Number	Lithology and fusulinids
2690–2695	90A	Limestone, fine crystalline, medium-gray weathering medium-gray, cut by many thin white calcite stringers; slightly brecciated at base; fusulinids in middle. *Schwagerina* cf. *S. jewetti.*
2700–2715	86A	Limestone, fine to medium crystalline, dark-gray, weathering dark-gray in top half and light-gray in lower half; contains fusulinids near top and syringoporoid corals in middle; coarsely crinoidal throughout; forms 10 to 12 foot ledge; weathered surface highly grooved and cut by many irregular calcite masses. *Triticites* sp. D and *Pseudofusulinella* sp. B.
2720–2725	84A	Limestone, fine crystalline, massive, medium-gray, weathering medium-gray; contains corals and fusulinids; weathered surface highly grooved and somewhat pitted. *Triticites* cf. *T. creekensis.*
2775–2790	68A	Limestone, massive, dark-gray, weathering medium and dark-gray; locally crinoidal and locally contains fusulinids; upper 2 feet are silty and contain porous brown chert nodules that have concentric structure; weathered surface highly grooved and cut by thin white calcite veinlets. *Triticites* cf. *T. creekensis.*
2825–2830	62A	Limestone, aphanitic, light-gray, weathering light-gray, highly jointed; contains fusulinids. *Schwagerina grandensis.*
3005–3015	32A	Limestone, somewhat silty, medium-gray, weathering medium-gray; forms prominent ledge below top of ridge; contains fusulinids near top surface; contains a small number of dark-gray chert nodules; also contains some white calcite nodular masses. *Pseudoschwagerina texana.*
3085–3095	23A	Limestone, massive, medium to dark-gray, weathering medium-gray and blue-gray; contains abundant scattered small gray and brown chert nodules; weathered surface highly grooved; contains abundant fusulinids especially near base and in lower 5 feet. *Pseudoschwagerina texana* and *Parafusulina* sp.
3210–3218	10A	Limestone, dark-gray to black, weathering dark-gray at base and light-gray at top; appears silty at top; contains gray chert. Bed is teeming with fusulinids, especially in the dark colored basal portion. *Schwagerina* sp. A and *Schwagerina* sp. B.
3220–3232	8A	Limestone, dark-gray, weathering dark-gray, containing small amount of gray chert nodules; weathered surface highly grooved; fusulinids about 1½ feet from top. Forms prominent ledge just west of main spur of traverse and so measured bed at that ledge. *Schwagerina* sp. C.
3555–3560	56B	Limestone, platy, with fusulinids. *Schwagerina elkoensis* and *Pseudoschwagerina* sp. A.
3575–3580	62B	Limestone, platy, in slabs ⅛ to ½ inch thick; contains fusulinids. *Schwagerina elkoensis* and *Schwagerina eolata.*
3603–3605	68B	Limestone, coquinoidal, arenaceous, light-gray, containing thin wavy bands composed of crinoidal material. *Schwagerina elkoensis.*
4025–4030	126B	Limestone, fragmental forming small ledge, medium blue-gray; contains crinoids and numerous fusulinids; cut by many calcite veins. *Schwagerina elkoensis.*
5140–5145	227B	Limestone, fragmental, crinoidal, medium-gray, weathering medium-gray; with abundant fusulinids. *Schwagerina wellsensis.*
5495–5530	243B	Limestone, dark-gray, massive; some beds are teeming with fusulinids; abundant chert nodules and irregular bands. *Schwagerina wellsensis.*

Stratigraphic height above base of formation (feet)	Bed Number	Lithology and fusulinids
5775–5815	270B	Limestone, very massive, forming most prominent ledge on top of ridge; dark-gray to medium-gray, weathering dark-gray, highly jointed, containing chert near base; locally contains silty layers. Fossiliferous, fusulinids 15 feet from base, and near top is zone of intermingled fusulinids and corals; contains large gastropods. *Parafusulina* sp. A.
5820–5835	273B	Limestone, finely crystalline, medium-gray, containing flat chert nodules; locally very fossiliferous with brachiopods, corals, large fusulinids; forms series of small steps. *Parafusulina* sp. A.
5850–5860	279B	Limestone, almost lithographic, medium-gray, weathering light and medium-gray, containing small brachiopods and fusulinids; chert in small flat nodules; unit weathers maroon near top. *Schwagerina* sp. D.
6010–6030	292B	Limestone, finely crystalline, dark-gray to black, weathering dark blue-gray and buff, locally silty; contains chert; pitted weathered surface; fossiliferous with crinoid stem plates, bryozoa, brachiopods; abundant fusulinids in top portion. *Schwagerina gumbeli.*
6080–6100	297B	Limestone, medium to dark-gray, weathering blue-gray; forms series of small steps; abundant black chert in large nodules and thin seams; large fusulinids, brachiopods. Unit partly concealed. *Schwagerina* sp. E.
6225–6230	303B	Limestone, medium-gray; weathering light-gray, buff, and rusty; interbedded with platy silty limestone; coquinoid; crinoidal, bryozoa, brachiopods, scattered fusulinids; contains dark-gray chert nodules. Forms base of small ledge. *Schwagerina* sp. F.
6230–6245	304B	Limestone, massive, medium to dark-gray, weathering dark blue-gray, forms prominent ledge; contains thin stringers of porous chert; fusulinids, especially near base. *Schwagerina* sp. F.
6245–6265	305B	Limestone, finely crystalline, light-gray and medium-gray, weathering light-gray and blue-gray; contains abundant thin gray chert nodules and seams; fusulinids scattered throughout, brachiopods. Forms series of small steps, each step 6 inches to 1 foot high; between the lower steps are zones of light-gray and tan weathering platy limestone. *Schwagerina* sp. E.
6285–6305	308B	Limestone, medium-gray, weathering blue-gray; contains thin flat chert nodules; abundant fusulinids, forms series of small steps. *Pseudofusulina* sp. A.
6310–6320	310B	Limestone, finely crystalline, dark-gray; contains pelecypods, abundant scattered fusulinids; contains rusty colored chert; unit partly concealed. *Schwagerina* sp. G.
6335–6350	312B	Limestone, almost lithographic, medium-gray to dark-gray, weathering light-gray and dark blue-gray and locally pink, contains large fusulinids; contains black chert nodules, especially near base; cut by thin calcite veins. *Schwagerina gumbeli.*
6350–6370	313B	Limestone, very finely crystalline, massive medium-gray, weathering light blue-gray, crinoidal; contains abundant gray chert nodules. Unit forms very prominent ledge. At base are alternations of silty and non-silty layers; the non-silty ones range from 3 to 8 inches in thickness, the silty ones from 1 to 3 inches. Fusulinids present at top. *Schwagerina gumbeli.*
6435–6440	317B	Limestone, finely crystalline, medium-gray, weathering light-gray and medium-gray; contains small amount of scattered chert; contains abundant large fusulinids. *Schwagerina gumbeli* and *Schwagerina* sp. G.
6545–6555	323B	Limestone, finely crystalline, medium-gray to dark-gray, weathering light-

Stratigraphic height above base of formation (feet)	Bed Number	Lithology and fusulinids
		gray and pink, platy; contains productid brachiopods and scattered fusulinids. *Schwagerina crassitectoria.*
6575–6605	326B	Limestone, medium gray to dark-gray, weathering medium-gray, interbedded locally with silty rusty weathering layers; contains porous brown chert; locally crinoidal, containing abundant large fusulinids. Forms series of steps, each about 2 feet high; cut by many thin calcite veins. *Schwagerina* sp. G.
6610–6620	328B	Limestone, finely crystalline, crinoidal, massive, medium-gray to dark-gray, containing abundant irregular brown weathering silty lenses and porous brown chert. Contains brachiopods, bryozoa; fusulinids at top. Forms ledge. *Schwagerina crassitectoria.*
6660–6695	333B	Limestone, finely crystalline, crinoidal, massive, medium-gray, weathering blue-gray; contains irregular silty lenses and layers up to 1½ feet thick which weather rusty; forms bold ledge; contains fusulinids in middle. *Schwagerina crassitectoria.*
6800–6810	341B	Limestone, massive, dark-gray, weathering medium-gray and dark-gray; contains small amount of chert; contains fusulinids; cut by many thin calcite veinlets. *Schwagerina crassitectoria.*

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THE SPECIES PROBLEM

J. MARVIN WELLER
University of Chicago

ABSTRACT—Paleontologists are developing progressively more interest in the biologic aspects of fossils. Some, who are particularly conscious of the deficiencies that mark much of the paleontology of the past, seem to accept uncritically certain ideas that are current among neontologists and especially geneticists. This applies, for example, to the concept of the so-called biologic species which is defined as an integrated, reproductively isolated, breeding group. Such a concept is useful, and the existence of such groups deserves recognition but they are too theoretical to have much practical value.

Species have been viewed in many different ways, and the principal species concepts are compared. Fundamentally, the species is a taxonomic unit as demonstrated by more than 200 years of usage by biologists. Therefore, the redefinition of species as breeding groups is ill-advised. The taxonomic species is indispensable, and changing the meaning of a well known word only necessitates the substitution of a new term for exactly the same thing.

A species definition is suggested that takes into account modern biologic thought, fits the requirements of paleontologists, and should be acceptable to many neontologists.

INTRODUCTION

THE species is the basic unit in biologic taxonomy, but it cannot be defined in any way that will satisfy all neontologists and paleontologists. This anomalous situation is the result of profound changes in the understanding of biologic relationships and ideas concerning taxonomic procedure. When organisms first were classified, species were believed to be uncomplicated things. Each was distinct from every other, and classification was based on more or less obvious differences which were not considered to imply any degree of actual blood relationship. Acceptance of the theory of evolution produced new ideas regarding the nature of species and the way in which they should be classified. The taxonomic framework, however, remained unchanged although some of its deficiencies in expressing newly recognized relations were soon realized. Advancing knowledge, particularly in genetics, introduced modified species concepts, and further disagreements have developed concerning both definitions and taxonomic practice. These are not likely to be resolved soon because of important divergencies in viewpoints. Both philosophical and practical aspects are involved in the attempt to integrate modern theory and knowledge with an ancient taxonomic system. Revision of this system is unlikely because it has been accepted for so long and because no more satisfactory system has been devised.

THE NEONTOLOGIC POSITION

Neontologists and paleontologists look upon species somewhat differently. Neontologists see organisms as they exist today. Living specimens are available for study, and these can be observed in as much detail as is desired. Not only morphology of all parts but also geographic ranges, relations to environments, habits, and functional activities can be studied, and breeding tests can be made.

Knowledge of any kind of organism necessarily is based on the observation of a sample because every individual of a species cannot be studied. The neontologist, however, generally can choose his sample. The number and distribution of his specimens are limited mainly by the time and effort devoted to their collection. If he wishes and has the opportunity to do so, a neontologist can take all the specimens within any number of selected areas throughout any region. If a preliminary study reveals deficiencies in the sampling or indicates that additional specimens from a particular area are needed to resolve uncertainties, further collections can be made. Certainly no species has been studied in sufficient detail and throughout its complete geographic range to reveal all

that can be learned about it. The opportunity to make such a complete study exists, however, and no absolutely insurmountable obstacle prevents a neontologist from obtaining all of the specimens he needs. This surely is true for terrestrial organisms and, with the perfection of apparatus for underwater exploration, the opportunities for studying aquatic organisms are rapidly improving. Therefore, no limits circumscribe the study of living organisms except those imposed by lack of the time or money needed for their accomplishment. Theoretically, a neontologist can reach opinions concerning species on the basis of any criteria applicable to living organisms that he wishes to investigate.

Neontologic studies, however, are limited with respect to passing time. This is important, and this is one of the principal factors responsible for divergencies in the viewpoints of neontologists and paleontologists. Studies of living organisms are essentially two-dimensional and involve consideration of geographic spacial relations and variations. An important third dimension is lacking in most neontologic thinking. Evolution is too slow for any person within his lifetime to observe its operation under natural conditions. Neontologists believe that evolution has occurred, that similar living species have descended from a common ancestor, and that the differences which separate them have developed more or less slowly as the modern species gradually diverged. Neontologists do not have to take this into consideration, however, when they compose definitions or classify organisms into species. Many groups of living organisms have diverged sufficiently to be unquestionably different and distinct, and no amount of searching will reveal transitional existing forms to bridge the gaps between them. These are unequivocal species to the neontologist. The connecting links are dead and, if they are ever found, they will be fossils and lie outside of the neontologist's field of study. Of course, all groups have not diverged so greatly, and some are still connected by transitional living forms. These do pose problems in the classification of modern organisms.

All neontologists who have thought about these matters certainly recognize that their field of operation lacks the time dimension. Most of them, however, seem to be so unaccustomed to thinking in terms of time that they discount the importance of this limitation. This is generally true even of geneticists who might be expected to have particular interests in evolutionary problems. They actually deal only with modern organisms, and their theoretical consideration of evolving ancestors evidently does not compensate for lack of real experience with historical material. This probably accounts for their common failure to understand why all considerations of plants and animals should not, or cannot, be accommodated to their ideas regarding species and other features of organic classification.

THE PALEONTOLOGIC POSITION

It is true that much paleontologic work has not kept pace with the progress of biologists who study living organisms. This, however, is not a valid reason to conclude that many paleontologists hold views concerning species and their definition which are inferior or out of date as compared with the current ideas of neontologists and especially geneticists. Indeed, it would be surprising if the opinions of workers in these different fields should coincide completely. All who are interested in past or present life should have the same objective: to learn as much as possible about organisms. The practical problems confronting paleontologists and neontologists, however, are not the same, and the materials with which they deal are very different. This is an important matter that is sure to influence their respective viewpoints.

In two respects, paleontologists labor at a great disadvantage as compared to neontologists: (1) Their specimens are dead and preservation is incomplete, and (2) their opportunities for sampling are severely limited. Obviously, this means that they never can understand the organisms with which they deal as completely as neontologists. In addition, the task of paleontologists is greatly complicated because they are vitally concerned with a three-dimensional framework of space and time rather than the two-dimensional geographic framework of neontology.

Imperfection of the fossil record is so obvious that little comment is required. Fossil

animals, with very rare exceptions, consist only of hard parts that are relatively resistant to destruction. Knowledge of their soft anatomy is restricted to inferences drawn from study of the hard parts and by analogy with similar living creatures. Very commonly, even the hard parts are incompletely preserved, as in a dismembered and scattered skeleton. Many fossils are variously damaged or distorted, and mineralization may have destroyed structural details. Moreover, the labor required to free specimens from enclosing rock is likely to limit the number of good specimens that can be prepared for study. Fossil plants almost invariably are fragmentary, and many of the specimens representing different parts cannot be associated with much assurance. Finally, ancient faunas and floras are incomplete because an unknown number and variety of organisms have not been preserved. Paleoecologic relations are obscure because many environmental features have left no clear record. Habits and functional activities cannot be observed, and breeding tests cannot be made.

Fossils can be collected only where fossil-bearing strata are accessible, and at most places only a limited number of specimens can be obtained. Commonly, the number is too small to represent a local population adequately. Very rarely is it possible to obtain a wide geographic representation of specimens known to be of closely similar age, even from the most common species. In a like way, collections of specimens from successive stratigraphic zones, closely enough spaced and continuous through a sufficiently long interval of time to show the detailed progress of evolution clearly, generally are unobtainable. Consequently paleontologists are forced to deal with scattered, mostly inadequate material whose detailed time relations are rarely accurately known.

Paleontologists necessarily consider time in connection with species. To them, evolution is something that is occurring, not something that has happened. They must evaluate variation and possible lateral discontinuities just as neontologists do, but their samples are less satisfactory and cannot be supplemented as desired. They also deal with vertical or time variability. Here observed discontinuities are not real as lateral discontinuities may be. Transitional forms connecting older and younger faunas and floras must have occurred; perhaps they will be discovered and then the discontinuities will disappear.

The paleontologist's view of an evolving organic continuum is much more complex than the neontologist's view of an essentially static situation such as exists at the present moment of geologic time. This difference has been depreciated by some. Nevertheless, it does exist, and it accounts for some of the lack of mutual understanding that is apparent.

SPECIES CONCEPTS

An extensive literature devoted to the species problem has grown up. Much of it is concerned with rather inconsequential philosophic, theoretical, and semantic details, and little is to be gained by reviewing it at length. Some consideration is necessary, however, to bring into proper perspective the different attitudes that have been and are still evident. In this way, various ideas concerning species can be compared and judged in relation to changing beliefs, theoretical matters regarded as important, and practical requirements.

Species as a General Idea.—Species is a Latin word meaning a *sight*, a *view*, or a *look* and likewise *that which is seen*, an *appearance*, a *form*, or a *figure*. It is practically synonymous with the Greek *eidos* from which the English word *idea* was derived. The word *species*, with such a general meaning, came to be used in many other related ways and, from very early times and in special connections, it conveyed the idea of *a certain kind of thing* as distinguished from other similar things. For example, it still is used in this way in mineralogy. When *species* was applied to organisms, it had a similar meaning and served to denote a kind of plant or animal more or less obviously different from other kinds.

Everyone makes distinctions of this sort. The species that he sees, however, depend upon his opportunities for observation and his interest, or the detail in which his observations may be made. To a city boy, all trees may look alike, but a country boy easily recognizes such different kinds as maples, oaks, and elms, and a trained

botanist sees many more subtle differences. In each case, qualities of both similarity and difference are involved in the recognition of species, and such a process of sorting out different and grouping similar things provides the basis for a classification. This may be done more or less unconsciously, as by the city boy who distinguishes trees from bushes but does not notice variability among the trees. The botanist, on the other hand, observes the trees minutely; he is interested in their differences which he is likely to consider more important than similarities.

In its general sense as applied to organisms, therefore, *species* is a word identifying the lowest class of taxonomic categories which stands next above the individual. It implies principally discrimination among organisms that are not further subdivided into lesser groups. According to this idea, a species is a simple thing. A biologist who observes only a local flora or a local fauna, or a paleontologist who studies fossils collected at a single place, generally has little difficulty in sorting out his specimens into what appear to be well differentiated species. This is the way most people see nature. Difficulties are likely to arise only when more extended or more critical observations bring to notice the variability within groups and the transitional forms which may connect them.

Species by Special Creation.—The foregoing concept of species is perfectly adapted to the belief that every kind of plant and animal arose independently as the result of a divine creative act. Religious faith for many years sustained the view that such creation provides a rational explanation for all diversity occurring in the organic world. It also served to perpetuate the idea that all species are discrete, and separable things even after difficulties were experienced in the actual separation of some of them by morphologic means.

Species as Discontinuous Groups.—The idea that species must be discontinuous groups continued to be held right up to the time when a theory of evolution gained acceptance by biologists. This was not a universal belief, however. The observation was made, particularly by botanists, that complete transition occurs between morphologic forms so different from each other that they had been considered separate species. This was interpreted by some as indication that species are not permanent, and that various unexplained transformations can occur even to the extent of a seed produced by one species growing into a plant belonging to another.

Most biologists, however, clung to the belief in discontinuity. They reasoned that, even if naturalists could not distinguish species certainly, individual organisms recognized their kindred, and different species would not interbreed. Of course, a few exceptions were well known, for example horse and ass, but the offspring of such crosses are infertile. Therefore, sterility is a test of interspecific discontinuity. This idea arose in the seventeenth century; it has been revived in modern times in a more sophisticated form.

Species as Taxonomic Units.—It is difficult to say when a definite system of classification based on species originated. The elements of such a system certainly go back to Aristotle's time. It was Linnaeus' work, however, that provided the foundation upon which all later taxonomy has been based. In the Linnaean system, species are recognized by their morphologic differences from each other. The species then are grouped in genera and higher taxonomic categories on the basis of various grades of similarity. This system emphasizes first differences and then similarities.

The labeling of every species with a name, which serves for its identification, conforms to the idea of discontinuous species. It does much more than this, however, because the naming of coordinate groups of such a kind confers upon each of them a distinct subjective individuality emphasizing differences at the expense of any similarities which may exist. It also seems to imply that every named species stands on an equal footing with all others. In practice, every specimen must be assigned to a previously recognized species, or a new species must be erected for its reception.

The Linnaean system makes no provision for any form intermediate between species. The subspecific categories recognized in later time do not do so either. They serve only to identify subdivisions of species characterized by minor differences. The

species, therefore, is a taxonomic unit no matter how else it may be interpreted. It is, in effect, a sort of pigeonhole that is convenient for the sorting out of those specimens which differ from others in some particular way.

Species as Morphologic Groups.—The Linnaean species has been defined as a morphologic species and vice versa. The concept of morphologic species, however, has implications beyond those that are simply related to a particular taxonomic system. As reviewed today, it suggests a grouping of individuals that may be unrealistic or improper.

A morphologic species, of course, is one that is identified by some more or less obvious physical peculiarity. Knowledge of modern organisms casts doubt on such identifications because: (1) Some species are polymorphic or polytypic and consist of individuals that, on the basis of form alone, would certainly be assigned to different species if not to even more remotely related taxonomic groups, and (2) some recognized modern species are so similar that they cannot be differentiated on the basis of any readily observed physical characters.

Some modern species show pronounced sexual dimorphism, or polymorphism related to successive developmental stages, alternation of generations, or divisions of labor and function in colonies. Others are represented in different areas by well marked polytypic forms that have not diverged sufficiently to be considered separate species. Also environmental influences have acted upon some individuals to produce distinctive phenotypic variants. The relations connecting different forms of organisms of these kinds commonly were unsuspected or improperly understood before they were diligently studied. All such forms have not yet been recognized for what they really are.

Exactly the opposite relations characterize sibling species. These are groups of organisms so similar that they are not easily distinguished morphologically, but evidently they differ in some subtle but important way because they are isolated reproductively and cannot or will not interbreed. Sibling species are rarely suspected to exist until breeding habits are studied and their distinctness has been demonstrated. After they are discovered, more detailed observations may or may not reveal slight morphologic differences.

Many species can be recognized morphologically, but reliance on form alone is not decisive because some closely related organisms will be separated unnaturally and some others, that seem deserving of differentiation will not be distinguished.

Species as Typologic Groups.—Species distinguished morphologically can be defined either (1) with reference to a type specimen, or (2) as populations.

The rules of biologic nomenclature that are recognized universally encourage typologic classification. They provide that every species name is attached inseparably to some particular single specimen, and the name is applicable to all specimens of the species which include this type. Although nothing in the rules indicates that the type is more than a name-bearer, the importance attached to it naturally focuses attention upon this specimen. Commonly, identifications are made by comparing specimens morphologically with types, and generally the latter are looked upon as central points about which other specimens cluster. Actually, a type specimen may occupy a position anywhere within the range of variability of a species population, and there is no guarantee that it is not a relatively aberrant representative not at all typical of the species morphologically.

Most species of plants and animals, both modern ones and fossils, were recognized originally on the basis of too few specimens to be an adequate sample of a population. Very commonly only a single specimen was carefully observed. Such species are necessarily typologic, and they remain so until enough additional specimens have been collected and compared to reveal the variability of a population. Relatively few species actually have been studied in this way.

Form Species.—Form species are fossil typologic species of a special kind. They consist of separate structural parts or fragments of organisms, commonly found in such a dismembered condition that their proper associations rarely can be determined, or markings of several kinds that provide little information about the organisms that produced them. Some are known to occur in

various combinations in such a way that different kinds certainly are parts of the same organism. Furthermore, some of these parts, so similar that they are grouped together as single or related species, are known to occur in organisms that would be classed as different genera if they were considered as a whole.

Form species are set apart completely from all other kinds because they are entirely and admittedly artificial. They require recognition, however, for practical reasons. Paleontologists must deal with them because some are common fossils, and some are very useful for stratigraphic correlation. They must be identified and classified in some way and by custom they have been treated in accordance with the Linnaean system. So-called species of this kind should not be permitted to confuse the concept of more realistic species.

Species as Abstract Groups.—The foregoing consideration of several different species concepts indicates that the species, as commonly recognized in the past, is a more or less abstract and artificial taxonomic category with no certain meaning in biology. Its deficiencies have become increasingly apparent to neontologists and paleontologists alike. The acceptance of evolution as a continuing biologic process also beclouded previous concepts because the idea was introduced that species are forever changing. Some biologists have contended that the species is a fiction or a mental concept without reality. To them, a species could be defined only as a *group of similar organisms which is considered to be a species by a competent specialist.* Such a definition is almost meaningless. Others specified that the group consists of *similar and presumably closely related individuals.* This helps a little, but not much, because an opinion is required and almost every investigator is sure to be convinced that he is competent to evaluate and interpret the particular group of organisms with which he happens to be concerned.

Obviously, the species concept requires careful study and constructive reappraisal if it is to acquire biologic meaning.

Species as Populations.—Every species, no matter how it is interpreted, consists of individuals, and individuals are bound to vary. Therefore, a species cannot be characterized realistically by any single individual such as a type specimen. Its only valid basis is the entire group of individuals or the population that it comprises. The population can be defined with reference to its characters and the ranges of their variability, or in some other apparently meaningful way.

A species of this kind is, theoretically, objective and it is biologically meaningful. The problem that arises, however, is: How is a natural species population to be recognized? An answer can be sought intuitively or by the statistical analysis of morphology which generally furnishes better basis for a judgement.

Any collection of specimens is a statistical sample that can be investigated and compared with other samples. If it is a good one, analysis will show whether or not a discontinuity occurs within it or between it and other samples, and discontinuities can be tested for significance. An important morphologic discontinuity may indicate that two populations require differentiation. No automatic answer concerning species or their populations, however, is provided but areas of doubt are greatly narrowed.

To be tested in this way, specimens must be reasonably abundant, and samples must be distributed adequately so that discontinuities are real and do not result only from lack of information concerning gradual transitions. Many species are represented by too few specimens in collections to make such testing possible.

Species as Breeding Groups.—The mating opportunities of an individual organism ordinarily are restricted to a limited number of other individuals which occur in close proximity, and together they constitute a local population. Populations of this kind overlap peripherally in a complex way and altogether form a more or less extensive breeding group with definite outer boundaries. Gene flow is possible throughout this larger population and all its parts.

Geneticists believe that such a breeding group, which is isolated reproductively from all others, is the only realistic and significant biologic unit. The individual is not important because individuals are impermanent and individuals with different genetic qualities

replace each other constantly. Other groups of individuals, such as strains, races, and subspecies, are equivocal because they are not isolated from each other; they intergrade and can either gain or lose more or less distinctive features relatively easily. The larger breeding group, however, remains essentially unaltered except for very slow evolutionary change. Geneticists term it a *biologic species* although *genetic species* would be a better name.

A breeding group is a population but it is not defined by physical form or character like a morphologic population. It is a continuous and integrated genetic unit.

Species of Asexual Organisms.—Many organisms reproduce mainly asexually by various types of fission or budding, or by self-fertilization. Most of these, however, make some provision for occasional sexual crossing, and, consequently, they can be classified in species corresponding to other more freely interbreeding groups. Some organisms, however, are not known ever to reproduce sexually, and there are those so constituted that sexual reproduction is believed to be impossible. Among such organisms, there is no gene flow throughout a population except that which occurs directly from parent to offspring. Each of these individuals at any moment is, in effect, an isolated genetic unit, and so-called biologic species do not exist.

This situation is met in one of two ways: (1) The declaration is made that there are no species of such organisms, or (2) species here are differentiated on the basis of morphologic or physiologic discontinuities comparable to those observed to occur between biologic species. Groups so distinguished are, of course, taxonomic species. Biologists who subscribe to the biologic species concept have proposed that these latter groups be known by a special name, such as *agamon* or *binome*, to emphasize their difference from proper species.

Species Difficulties.—The species concept encounters serious difficulties in the case of well marked divergent groups that are connected by transitional forms. Two different situations of this kind exist: (1) Large groups of organisms that have evolved in different areas to produce easily distinguished forms which certainly would be considered separate species if discontinuities had developed. These are incipient species occupying a position intermediate between the ordinary subspecies of a polytypic population and proper species marked off from each other by reproductive isolation. Examples are known among both plants and animals. Organisms so related should be expected to occur in some proportion at any time if evolution is in operation.

(2) Large groups of organisms that appear to consist of two or more well marked species occupying overlapping ranges, which are distinct in some areas, but in others are connected by such abundant, transitional, and presumably hybrid forms that differentiation is not possible. Hybrids are known to occur in nature between many closely related species of both animals and plants. In animals, they generally are not abundant and rarely introduce serious difficulties in the differentiation of modern species. The genetic constitution of plants, however, is somehow different and reproductive isolation apparently is not so readily attained. Many hybrid swarms are known to botanists. They introduce so much confusion that few good species can be recognized in some genera of plants.

Species as Phylogenetic Groups.—Biologic taxonomy was formulated by neontologists for modern organisms. Its application to historical material by paleontologists has, on the whole, been a relatively minor side development. This does not mean, however, that certain difficulties or deficiencies of taxonomy clearly recognized by paleontologists are unimportant. Paleontologists assess problems of this kind from a legitimately different viewpoint which actually is more realistic than that of neontologists because the element of time is not neglected.

The foregoing varied species concepts have been presented mainly from the neontologic standpoint. Paleontologists can interpret species in exactly the same ways if their attention is restricted to fossils collected from a single stratigraphic zone. If every zone were considered independently, however, taxonomy would lose all meaning, and species would lack both practical and theoretical significance. The historical continuity of life certainly requires accommodation in any comprehensive species concept.

Neglect of the time element inevitably must result in serious misunderstanding of taxonomic relationships.

Consideration of the time element in biology necessarily requires revision and expansion of most species concepts advanced by neontologists since evolutionary theory gained acceptance. No matter how else a species may be defined, except in the narrowest typologic way, it is a group of sequent organisms presumably related by descent. This idea was clearly expressed by several preevolutionary biologists. The individuals that lived at any time are only a sample of such a sequence, and the species itself is a phylogenetic group. No evolutionary implications are inherent in this view but, of course, they are not excluded either. Temporal samples can be compared like geographic samples. They may be expected to reveal evolutionary variation comparable in a way to geographic variation. More complex relations than in a geographic sequence, however, are almost certain to be involved, and no real discontinuities can have broken an evolving lineage to provide boundaries between successive phylogenetic species.

MODERN CONFLICT OF IDEAS

The many different ideas associated with the species concept seem to create a situation of great complexity. The suggestion has been made that much confusion can be eliminated by recognizing three kinds of species: (1) The morphospecies, or morphologic species—a group of morphologically similar organisms, (2) the biospecies, or biologic species—a two-dimensional, potentially interbreeding group isolated from all similar groups, and (3) the paleospecies, chronospecies, or phylogenetic species—a three-dimensional integrated phyletic succession of biospecies. None of these, as commonly defined however, meets the desirable requirements of a species, and all three of them together do not adequately provide species concepts applicable to every need. Furthermore, a comprehensive species concept is complicated unnecessarily by the implication that several different kinds of species should be recognized.

In its last analysis, the species is a useful construct created by biologists for their convenience. Individually and in varying degrees, biologists are interested in (1) providing a basis for a classification that is practical, and (2) portraying as closely as possible the patterns of biologic relationships as these actually occur in space and time. Either of these objectives might be attained alone, but together neither can be realized completely. In a synthesis, some concession must be made on the part of each point of view.

Most of the controversy concerning species involves little more than relative emphasis. Much of the misunderstanding, which seems to be largely semantic, can be cut through by asking two questions and attempting to answer them. These are: (1) What *is* a species?, and (2) What *constitutes* a species? Although similar, these questions are not the same. The first yields rather readily to an answer; the second involves a matter of opinion.

What is a Species?.—A species is a *taxonomic unit*. It is a *formal biologic unit* identified by a *specific name*. This may not seem to be a satisfactory answer or definition but, considering that the second question follows, it is the only one that is either necessary or possible. Biologic nomenclature is governed by a system that requires the species. This system is wholly empirical, and it is not concerned in any way with how a species should be recognized.

What Constitutes a Species?.—According to past practice and modern ideas, species may consist of individuals that are (1) closely similar morphologically, or (2) closely related biologically. These two avenues of approach to the recognition of species reflect either the practical or the theoretical viewpoint that predominates in the thinking of every taxonomist. Actually the difference is not as great as it appears because, on the one hand, similar morphology generally is considered to imply close relationship and, on the other, relationship is likely to be indicated by similarity.

Almost all present day neontologists and paleontologists concede that relationship is the only possible basis for a classification which is biologically meaningful. At this point, however, mutual agreement ends, and differences in emphasis become apparent. Practically inclined persons accept the pre-

sumed significance of morphologic similarity in the absence of good evidence to the contrary. Others, in varying degrees, give preference to more obscure or less convincing evidence or to wholly theoretical considerations.

All paleontologists are aware of the possibility of homeomorphy among organisms of different ancestry which have retained or acquired similarity of form as a result of parallel or convergent evolution. Examples of sibling species are well known among modern animals, particularly insects and protozoans, whose life cycles and breeding activities have been studied closely. The occurrence of such siblings among fossils, however, probably never can be established certainly and, consequently, homeomorphy in paleontology is more a problem at a generic than at a specific level. Fragmentary fossil plants are particularly difficult because different structural parts varied more or less independently of each other. For example, different form species or even genera of fossil plants are known to be related in various complex ways. Differences of form in successive growth stages or in alternate generations are confusing in fossil animlas but, if enough specimens are available and they are studied carefully, these generally can be recognized and correlated properly.

The morphology of fossils is the principal kind of evidence upon which paleontologists must base their judgement concerning species. Although all uncertainty cannot be eliminated, morphology ordinarily is considered satisfactory if it is observed with care in adequate samples rather than in individual specimens. Practically, the situation with respect to modern organisms is not much different because most living plants and animals also are classified on the basis of morphology alone.

Less objective evidence has been variously evaluated and relied upon for species recognition. The most common kind is related to geographic range and the actual or inferred isolation of similar and probably closely related populations. For example, occurrence on different continents, on opposite sides of an ocean, or in the northern and southern hemispheres separated by the equatorial zone has been accepted, particularly in paleontology, as presumptive evidence of species difference. In fact, few North American paleontologists have made more than perfunctory comparison of their specimens with fossils from Europe, Asia, or South America. Some have been much more extremely provincial than others, and one American paleontologist regularly assumed that fossils collected at localities separated by more than a certain arbitrary distance must be different species no matter how similar they might appear to be.

In a comparable way, the association of organisms with different physical environments or in different biologic combinations has been taken to indicate probable species differentiation, although paleontologists rarely have made distinctions on this basis. Relative stratigraphic position and difference in age have been much more important considerations in paleontology. This involves the assumption that evolutionary divergence has occurred and is important enough to make close morphologic comparison unnecessary. A few paleontologists have been willing to describe new species from any formation which has not previously yielded similar specimens even though they do occur elsewhere in strata of only slightly different age.

Formerly, species were considered to consist simply of morphologically similar individuals. In modern times, attention has shifted more and more to biologic relationships, and the opinion now is widely held that species are made up of all the individuals that constitute a population integrated in space and time.

Biologic Species Concept.—The concept of species as populations carries with it the idea that populations are the biologic units that should be recognized and classified. Biologic populations are to be identified by their internal consistency and external discontinuity. These two definitive characteristics are believed to be determined by genetic factors that are reflected in morphology, geographic distribution, and ecologic preference. As emphasis has shifted from the objective qualities of populations to their presumed genetic nature, the opinion has developed among neontologists, and especially geneticists, that the species must be defined in genetic terms. Thus, definitions center around the concept that a

species is essentially a more or less extensive, integrated, but isolated breeding group. Some paleontologists who are particularly aware of the common deficiencies of paleontologic thought subscribe to this idea fully insofar as it can be adapted to their three-dimensional frame of reference involving both space and time.

The biologic species concept is attractive theoretically in some respects. When it is examined carefully, however, serious objections become apparent. Particularly objectionable is the insistence, by those who most consistently emphasize this concept, that no group defined in any other way can be a proper species. Obviously, breeding or genetic tests cannot be applied to fossils.

Another especially important objection is that the species is divorced completely from its ancient and most fundamental position as a taxonomic unit. No matter what it may be called, such a unit is required. Redefinition of the species, whose relation to taxonomy has been accepted universally for more than 200 years, does not make good sense if it is restricted in such a way that it cannot apply to the classification of all organisms, and a new and unfamiliar term must be introduced for exactly the same thing.

The so-called biologic species is rejected by some neontologists who recognize its inapplicability to the organisms with which they deal. Consideration centers around those plants and animals in which there are no breeding groups, although suitable species populations of similar and presumably closely related individuals can be identified by some objective means. Other populations have been discovered to consist of two or more parts that cannot interbreed. These parts are indistinguishable morphologically, and they can be recognized only after elaborate and very time consuming tests made on living specimens. Obviously, these parts cannot be regarded as practical taxonomic units. Their designation as species has been opposed.

Finally, application of the biologic species concept demands a detailed knowledge of the breeding activities of all plants and animals if it is to be useful. Such knowledge does not exist for the vast majority of living organisms and certainly it will not be gained for very many years to come. It never can be obtained for fossils. Consequently, the so-called biologic species is so highly theoretical that it can have no present taxonomic value. The concept is a useful one, and the existence of such a group at any moment in geologic time deserves recognition but it should be identified by some such name as *syngen* which has been proposed for it. This would not confuse a realistic species concept in an unnecessary way.

CONCLUSIONS

A species problem exists precisely because there is disagreement as to what a species is. There is even disagreement regarding the reality of species. Some differences of opinion certainly will persist long into the future because interests and viewpoints in biology are so varied. Nevertheless, an attempt can be made to compose a species definition that will meet with the approval of most paleontologists and many neontologists. The principal points that require consideration are as follows:

1. The species is a formal taxonomic unit. More than two centuries of taxonomic practice have established the species as the basic unit of biologic classification. Some writers appear to scorn, as unscientific, the practical aspect of species that this implies. Recognition of the species as such a unit cannot be abandoned, however, without confusing the entire structure of biologic classification.

2. Species are to be identified by specific names. Species exist whether they are recognized or not. When a species is recognized, it is given a specific name. Every name, however, does not necessarily identify a species, except provisionally, because specimens may be mistakenly interpreted—see next item.

3. The species is a population. If a species is defined as a group of individuals, the individuals receive primary attention, the species is a second order concept, and consequently it is subjective. Defined as a population, a species is a first order concept, and it possesses whatever reality is conferred upon it by the structure and organization of the population. If the population is properly interpreted, the species is a significant biologic unit. The fact that

many nominal species have been based on too few specimens to represent a population adequately does not invalidate these statements. It indicates only that such nominal species are insecure and subject to revision or suppression as populations become better known.

4. The species is a continuing population. The species is, in effect, a three-dimensional population because it persists through some appreciable interval of time. Neontologists generally ignore this aspect of the species and, consequently, most of their definitions are unacceptable to paleontologists. Continuence does not necessarily imply that evolutionary change occurs persistently but most species certainly did evolve.

5. Individual members of a species are related. This is not likely to be denied by anyone, but the nature of relationship is indeterminate and it is not necessarily the same for every species. Ideally, the relationship is that of an integrated interbreeding group but all species do not have this structure. The ancestor-descendant relationship is important in a continuing population, and this may be the only one occurring in certain asexual or self-fertilizing species. Theoretically, perhaps, relationship should be expressed in terms of genetic similarity but this concept is not useful in a practical definition.

6. Individual members of a species generally are morphologically similar. This also is not likely to be denied, but more or less remarkably different forms may occur in polymorphic or polytypic species, successive developmental stages, or environmentally influenced phenotypes. From the practical standpoint, however, morphology is exceedingly important because conclusions concerning relationships in most species are based on little besides morphologic characters.

7. Species are distinct rather than different from each other. Species are distinct, that is, each is separated from every other contemporary species by discontinuity. This is not the same as being different, although difference is important, because the range of morphologic variation may overlap considerably in species which resemble each other in many ways. Reproductive discontinuity is theoretical, so far as most species are concerned, but this is inferred confidently on the basis of morphology in many instances. Reproductive discontinuity, however, may occur within some species whose parts are so similar that there is no practicable way to separate them—see next item.

8. Species are distinguishable. A practical taxonomic unit must be recognizable. This does not necessarily mean that every specimen shall be identifiable, but some reasonably apparent character or combination of characters must be evident that will permit the discrimination of different species. Ordinarily, morphology is relied upon especially in fossils. Absolute difference, however, is not necessarily demanded, and many species are distinguished on the basis of more or less qualitative differences.

9. Successive species in an evolutionary lineage are separated arbitrarily. Because of evolutionary continuity, there can have been no real morphologic or reproductive gaps between ancestral species and their descendants. Each species, therefore, is some arbitrary segment of a continuous evolutionary lineage. Observed discontinuities between specimens occurring in different stratigraphic zones result from incompleteness of the fossil record. These make convenient boundaries between sequent species but, if they are filled by specimens found in some other area, the distinctiveness of the species may disappear. This kind of relationship accounts for the different ways in which neontologists and paleontologists view species. The neontologic species, considered without respect to time, is non-arbitrary and objective. In contrast, the paleontologic species is, in a sense, an abstraction. If it is set off from others by important gaps, it is for all practical purposes just as real as a neontologic species. Two of its boundaries, however, are determined by chance or by choice, not by any real discontinuity. From this standpoint, the species is an arbitrary unit or convenient concept without any clear-cut biologic reality in its own right.

Species Definition.—In the light of the foregoing considerations, a species may be defined as follows: *A species is a formal unit of biologic taxonomy, to be identified by a specific name, consisting of a natural continuing population of individuals presumably closely related to each other and generally similar*

morphologically, that is distinct and distinguishable from all other contemporaneous populations, and separated from related ancestral and descendant populations at some convenient but arbitrarily selected boundaries.

The framing of a satisfactory species definition unfortunately does not solve the species problem. It only provides a standard against which proposed species can be judged. Most currently recognized species do not meet this standard in one or several ways because natural populations are inadequately known or incompletely studied. This is true of almost all paleontologic species. As greater knowledge is attained, however, continuing attempts can be made to bring them closer and closer into accordance with the standard.

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LOWER MISSISSIPPIAN ARENACEOUS FORAMINIFERA FROM OKLAHOMA, TEXAS, AND MONTANA

RAYMOND C. GUTSCHICK, JOHN L. WEINER, AND LEIGHTON YOUNG
University of Notre Dame, Notre Dame, Indiana

ABSTRACT—The purpose of this study is to call attention to the widespread occurrence of early Mississippian arenaceous Foraminifera in the United States and to classify the faunas for subsequent systematic detailed studies. They are represented in Lower Mississippian rocks from the Welden limestone of Oklahoma, Chappel limestone of central Texas, and Lodgepole limestone of southwestern Montana, and they are compared with a similar described fauna from the Rockford limestone of northern Indiana. Eleven genera and 33 species, 12 of which are new, are identified from among the families Astrorhizidae, Saccamminidae, Hyperamminidae, Reophacidae, Tolypamminidae, and Lituolidae. A summary is given of species in early Mississippian strata in the United States which total 16 genera and 49 species.

The Welden, Chappel, and Rockford faunas are considered to have been deposited in cool shallow aerated waters which were affected by wave and current energies just strong enough to produce turbidity. The Lodgepole limestone in southwestern Montana was deposited in deeper less aerated waters at the edge of the open marine shelf (basin edge) corresponding to Rich's clinoform depositional environment. While arenaceous Foraminifera are common, calcareous forms have not been recognized in these rocks.

INTRODUCTION

UNTIL recently little was known concerning early Mississippian arenaceous Foraminifera faunas in the United States. The study by Gutschick & Treckman (1959) of an extensive fauna in the Rockford limestone of northern Indiana indicates the diversity and abundance of this animal group in rocks of this age. A review of the literature concerning foraminiferal micropaleontology of early Mississippian rocks in this country is given in the annotated bibliography of Toomey (1959) and the summary by Gutschick (1960). This paper documents faunas from the Welden limestone of Oklahoma, Chappel limestone of central Texas, and Lodgepole limestone of southwestern Montana that are closely related to the Rockford limestone Foraminifera of Indiana. The combined faunas, exclusive of the Rockford, include 11 genera and 33 species of which 12 are new. With the Rockford fauna the total is 16 genera and 49 species.

We are grateful to George Thomas, formerly with Ohio Oil Company of Ardmore, Oklahoma, for help in securing Welden limestone from the type area. We are also indebted to Wayne Lowell and Judson Mead of the Indiana University Geologic Field Station in southwestern Montana for help and encouragement with the field work on the Lodgepole limestone part of the study. The types will be deposited in the U. S. National Museum.

PREPARATION OF SAMPLES

Limestone samples from each of the localities were washed, soaked, and treated with full strength commercial hydrochloric acid so that the carbonate was completely digested in the shortest possible time. Residues were washed and dried by oven and then treated with alcohol and dried to produce clean discrete particle samples for binocular examination. Samples were carefully sieved to facilitate search for the microfossils.

The camera lucida (Zeiss model 504/G/E) was used to make the drawings. Specimens were treated with glycerin and alcohol for the photography. The standard Rock-Color Chart was used for color descriptions of the lithologies.

In order to summarize the pertinent stratigraphic information on the details of occurrence of the Foraminifera in the three areas, the formations with their faunas will be discussed separately. Text-figure 1 is a stratigraphic chart of these sections showing their correlation. Graphic sections to illustrate general lithology, stratigraphic se-

STANDARD SECTION				FORAM ZONES	MONTANA		TEXAS	OKLAHOMA	INDIANA
MISSISSIPPIAN	LOWER	OSAGE	Keokuk		Madison group	Mission Canyon ls.			Borden gr.
			Burlington						New Providence sh.
			Fern Glen						U. Rockford sh.
		KINDERHOOK	Chouteau	F		Lodgepole ls.	Chappel ls.	Welden ls.	Rockford ls.
				F		*Little Chief Canyon mem.*		Pre-Welden shale	Jacobs Chapel shale
			Maple Mill				Houy fm.		Henryville sh.
									Underwood sh.
									Falling Run mem.
			Louisiana	F		Sappington fm.			Sanderson sh.
DEV.	U.				Threeforks shale		Houy fm.	Woodford shale	New Albany sh. Blackiston sh.

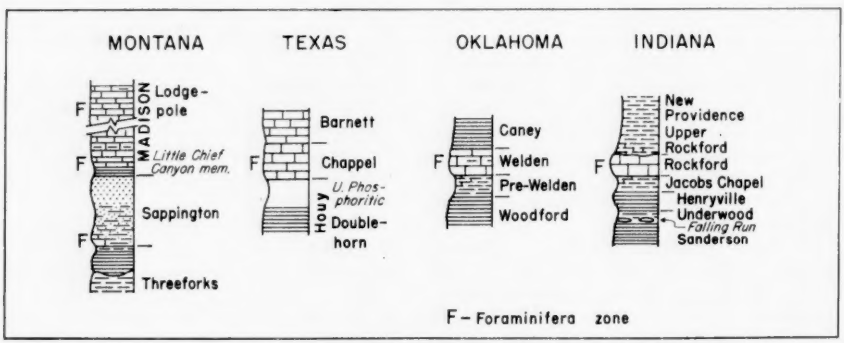
TEXT-FIG. *1*—Stratigraphic chart of Lower Mississippian sections showing correlation of Welden, Chappel, Lodgepole, and Rockford stratigraphic units.

quence, and position of foraminiferal faunas are given in Text-figure 2.

WELDEN LIMESTONE

Information on the stratigraphy of the Welden limestone can be found in Morgan (1924), Cooper (1939), and Champlin (1959), and current regional correlation in Branson (1957, 1959). Arenaceous Foraminifera were obtained from the Welden limestone at the type section, locality 1, and the Jackfork Creek Section, locality 2, of the eastern Arbuckle Mountains, Oklahoma.

The Welden is a light bluish gray fine-grained argillaceous limestone with scattered fragmental fossiliferous material including crinoid debris. This carbonate unit is about 3 feet thick and weathers grayish orange. Hydrochloric acid residues are about 2–3% of the original sample and consist principally of white to grayish orange soft powdery granular cellular or porous siliceous leached rock matrix and pale yellow-green flaky waxy clay or shale. Silicified fossils, including the arenaceous Foraminifera, make up less than 5% of the residue. Conodonts, ostracodes, and echinoderm fragments, including microcrinoids, are known



TEXT-FIG. *2*—Generalized stratigraphic sections to show relationship of Foraminiferal zones to lithology and sequence.

to be associated with the foraminifera fauna.

The following is a list of the arenaceous Foraminifera recognized in the Welden limestone of its type area in Oklahoma:

* *Pseudastrorhiza conica*, n. sp.
Pseudastrorhiza delicata? Gutschick & Treckman
Pseudastrorhiza lanceola, n. sp.
* *Saccammina ligula*, n. sp.
Lagenammina sphaerica Moreman
Thurammina diforamens Ireland
Thurammina furcata Gutschick & Treckman
Thurammina quadritubulata Dunn
Thurammina triradiata Gutschick & Treckman
Thurammina tubulata Moreman
* *Hyperammina conica*, n. sp.
Hyperammina constricta Gutschick & Treckman
* *Hyperammina gracilenta* Gutschick & Treckman
Hyperammina rockfordensis Gutschick & Treckman
Tolypammina cyclops Gutschick & Treckman
Tolypammina rotula Gutschick & Treckman
* *Tolypammina sperma*, n. sp.
Ammovertella bulbosa Gutschick & Treckman
Ammobaculites chappelensis, n. sp.
Ammobaculites leptos Gutschick & Treckman
Ammobaculites pyriformis Gutschick & Treckman

* Designates that the holotype specimen is from this formation.

CHAPPEL LIMESTONE

Information concerning the Chappel limestone of central Texas and its current status can be found in Plummer (1950), Cloud, Barnes & Hass (1957), and Hass (1959). The Foraminifera upon which this study is based were collected from the Chappel limestone (restricted) at the White's Crossing section of central Texas, locality 3. The strata correspond to Plummer's Espey Creek limestone member excluding the basal 15 inches referred by him to the Chappel at Espey Creek.

Lithologically the Chappel is pale red to grayish orange pink, fine-grained to partly crystalline crinoidal fossiliferous limestone with scattered pink crinoid debris and other fossil hash. This rock unit is about 1 foot thick.

The acid residues are about 1% of the total sample consisting of 40–45% white to limonitic granular soft cellular silicified leached rock matrix, 35–40% arenaceous Foraminifera, 15% moderate yellow-green waxy shale flakes and chunks and yellow-gray dull clay chunks, and 2–3% scattered single rounded frosted etched quartz grains.

A study of hydrochloric and acetic acid residues along with thin sections indicates that the following fauna is associated with the foraminifers: abundant conodonts (Hass, 1959), ostracodes, fish teeth, much echinoderm hash including microcrinoids, holothurian sclerites, and other crinoid debris.

Initial recognition of Foraminifera in the Chappel limestone came from samples which were collected on June 22, 1945, during a field conference conducted by Cloud, Barnes, and others.

The following is a list of the arenaceous Foraminifera recognized in the Chappel limestone of Central Texas:

Pseudastrorhiza delicata Gutschick & Treckman
Saccammina ligula, n. sp.
Lagenammina sphaerica Moreman
* *Thurammina arenacorna*, n. sp.
* *Thurammina congesta*, n. sp.
Thurammina echinata Dunn
* *Thurammina pustulosa*, n. sp.
Thurammina tubulata Moreman
Hyperammina conica, n. sp.
Hyperammina constricta Gutschick & Treckman
Hyperammina rockfordensis Gutschick & Treckman
Tolypammina cyclops Gutschick & Treckman
Tolypammina extenda? Ireland
Tolypammina rotula Gutschick & Treckman
Tolypammina sperma, n. sp.
Ammovertella bulbosa Gutschick & Treckman
* *Ammobaculites chappelensis*, n. sp.
Ammobaculites leptos Gutschick & Treckman
Ammobaculites pyriformis Gutschick & Treckman

* Designates that the holotype specimen is from this formation.

LODGEPOLE LIMESTONE

Little has been published concerning the detailed paleontology of the Lodgepole limestone formation. General information on this unit in southwestern Montana can be found in Sloss & Hamblin (1942), Berry (1943), and Holland (1952). The Foraminifera for this study were obtained from the basal and middle parts of the formation at two different localities. The lower collection comes from the bottom 10 feet at locality 4. The material from locality 5 was collected from near the middle of the formation. A more detailed study is being made to determine the stratigraphic micropaleontology of the Lodgepole in southwestern Montana.

The rock in both cases is a medium dark gray, fine-grained argillaceous limestone with much scattered fine fossil debris, including crinoid fragments. The rock is thin-bedded and weathers nodular, light to medium light gray in color with silicification of the fossils which etch in relief to give the weathered surface a gritty hackly feel. The thickness of the formation is 500 to 600 feet in the area sampled.

Hydrochloric acid insoluble residues amount to 1–2% of the original sample. They consist of soft granular siliceous rock matrix and powdery clay. They also contain much silicified fossil material, including the Foraminifera, cup corals, bryozoans, brachiopods, sponge spicules, crinoid fragments, ostracodes, and microcrinoids. There is some fine quartz sand in the residue.

Acetic acid residues contain abundant conodonts, fish teeth, holothurian sclerites, and glauconite. The basal zone has much more quartz silt and fine sand as compared to the middle zone.

The following is a list of arenaceous Foraminifera recognized in the basal 10 feet of the Lodgepole limestone of Montana:

* *Pseudastrorhiza baccula*, n. sp.
Pseudastrorhiza delicata? Gutschick & Treckman
* *Pseudastrorhiza digitata*, n. sp.
* *Pseudastrorhiza lanceola*, n. sp.
Sorosphaera geometrica Eisenack
Reophax calathus, n. sp.
Reophax sp.
Trepeilopsis glomospiroides Gutschick & Treckman
Tolypammina cyclops Gutschick & Treckman
Ammobaculites leptos Gutschick & Treckman

The following was collected from near the middle of the formation.

Hyperammina kentuckyensis Conkin
Hyperammina rockfordensis? Gutschick & Treckman
* *Reophax calathus*, n. sp.
Reophax lachrymosa? Gutschick & Treckman

* Designates that the holotype specimen is from this collection in the formation.

LOCALITIES

Collections of arenaceous Foraminifera were made from the Welden limestone of Oklahoma, Chappel limestone of Central Texas, and the Lodgepole limestone of southwestern Montana in the places described below.

Locality 1—Type section of the Welden limestone along old abandoned railroad right-of-way in the NW¼ NW¼ sec. 27, T. 3 N., R. 6 E., Stonewall Quadrangle, Pontotoc County, Oklahoma, about 4 miles south of Ada (Morgan, 1924; Cooper, 1939).

Locality 2—Jackfork Creek section near the center SW¼ NW¼ sec. 35, T. 3 N., R. 6 E., Stonewall Quadrangle, Pontotoc County, Oklahoma, about 6 miles south of Ada. The creek flows over the Welden limestone and produces an exposure along the bank. The middle part of the Welden is shaly at this locality.

Locality 3—White's Crossing section of the Chappel limestone. The exposures are northwest of White's Crossing, a crossing on the Llano River, 8.3 miles (airline) southwest of the courthouse at Mason, Mason County, Texas, along the northeast bank of the Llano River on the highway (farm road). (Plummer, 1950; Cloud & Barnes, 1948; Hass, 1959).

Locality 4—South side of the Carmichael Canyon (Pony) Fault, from the lowest 10 feet of the Lodgepole limestone in the southwest part of the SE¼ SW¼ to the northeast part of the SW¼ SW¼ sec. 21, T. 1 S., R. 3 W., Harrison Quadrangle, Madison County, Montana. This line of outcrops is 0.5 to 1.0 mile west and northwest of Indiana University's Geological Field Station (Berry, 1943).

Locality 5—Section east by southeast of Doherty Mountain along the south side of Cottonwood Canyon road in the sharp draw which can be seen from the road. Collection comes from talus and outcrop along the base of the slope from near the middle of the Lodgepole limestone in the SW¼ NE¼ sec. 33, T. 2 N., R. 2 W., Jefferson Island Quadrangle Jefferson County, Montana. This is also in the Indiana University Geological Field Station summer mapping area (Berry 1943).

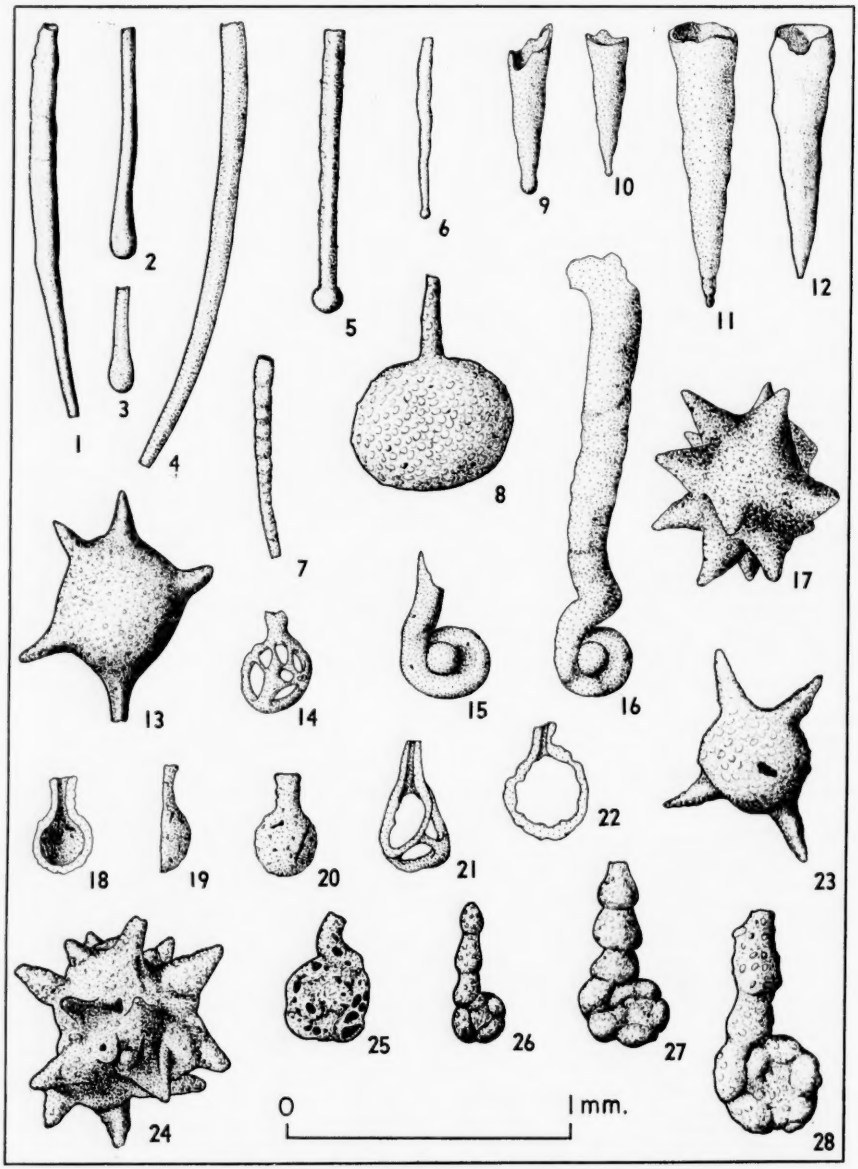
DISCUSSION OF FAUNAS

Comparison is made of the Welden, Chappel, Lodgepole, and Rockford foraminiferal faunas. The Welden fauna has the greatest abundance of *Hyperammina conica*, n. sp., *Ammobaculites pyriformis* Gutschick & Treckman, and *Lagenammina sphaerica* Moreman. The next important grouping is

TABLE 1.—SUMMARY OF THE OCCURRENCE OF ARENACEOUS FORAMINIFERA IN LOWER MISSISSIPPIAN ROCKS OF OKLAHOMA, TEXAS, MONTANA, AND INDIANA

Formation—	WELDEN		CHAPPEL	LODGEPOLE		ROCKFORD
Locality—	1	2	3	4	5	
ASTRORHIZIDAE						
Astrorhiza? sp.	–	–	–	–	–	×
Pseudastrorhiza baccula, n. sp.	–	–	–	⊗	–	–
Pseudastrorhiza conica, n. sp.	×	⊗	–	–	–	×
Pseudastrorhiza delicata G. & T.	–	?	×	?	–	⊗
Pseudastrorhiza digitata, n. sp.	–	–	–	⊗	–	–
Pseudastrorhiza lanceola, n. sp.	×	–	–	⊗	–	–
SACCAMMINIDAE						
Psammosphaera cava Moreman	–	–	–	–	–	×
Sorosphaera geometrica Eisenack	–	–	–	×	–	–
Sorosphaera papilla G. & T.	–	–	–	–	–	⊗
Saccammina ligula, n. sp.	⊗	×	×	–	–	×
Lagenammina sphaerica Moreman	×	×	×	–	–	×
Thurammina arenacorna, n. sp.	–	–	⊗	–	–	–
Thurammina congesta, n. sp.	–	–	⊗	–	–	–
Thurammina diforamens Ireland	×	–	–	–	–	×
Thurammina echinata Dunn	–	–	×	–	–	–
Thurammina furcata G. & T.	×	×	–	–	–	⊗
Thurammina limbata Dunn	–	–	–	–	–	×
Thurammina pustulosa, n. sp.	–	–	⊗	–	–	–
Thurammina quadritubulata Dunn	×	–	–	–	–	×
Thurammina triradiata G. & T.	×	–	–	–	–	⊗
Thurammina tubulata Moreman	×	×	×	–	–	–
HYPERAMMINIDAE						
Hyperammina bulbosa C. & W.	–	–	–	–	–	×
Hyperammina compacta G. & T.	–	–	–	–	–	⊗
Hyperammina conica, n. sp.	⊗	×	×	–	–	–
Hyperammina constricta G. & T.	×	×	×	–	–	⊗
Hyperammina gracilenta G. & T.	⊗	×	–	–	–	×
Hyperammina kentuckyensis Conkin	–	–	–	–	×	–
Hyperammina nitida G. & T.	–	–	–	–	–	⊗
Hyperammina rockfordensis G. & T.	×	×	×	–	?	⊗
REOPHACIDAE						
Reophax buccina G. & T.	–	–	–	–	–	⊗
Reophax calathus, n. sp.	–	–	–	×	⊗	–
Reophax lachrymosa G. & T.	–	–	–	–	?	⊗
Reophax sp.	–	–	–	×	–	?
TOLYPAMMINIDAE						
Ammodiscella virgilensis Ireland	–	–	–	–	–	?
Ammodiscus exsertus (Cushman)	–	–	–	–	–	×
Ammodiscus longexsertus G. & T.	–	–	–	–	–	⊗
Ammodiscus semiconstrictus (Waters)	–	–	–	–	–	×
Glomospira articulosa Plummer	–	–	–	–	–	×
Trepeilopsis glomospiroides G. & T.	–	–	–	×	–	⊗
Trepeilopsis prodigalis G. & T.	–	–	–	–	–	⊗
Trepeilopsis recurvidens G. & T.	–	–	–	–	–	⊗
Trepeilopsis spiralis G. & T.	–	–	–	–	–	⊗
Tolypammina botonuncus G. & T.	–	–	–	–	–	⊗
Tolypammina cyclops G. & T.	×	×	×	×	–	⊗
Tolypammina extenda Ireland	–	–	?	–	–	×
Tolypammina rotula G. & T.	×	×	×	–	–	⊗
Tolypammina sperma, n. sp.	⊗	×	×	–	–	×
Tolypammina sp. A	–	–	–	–	–	×
Tolypammina sp. B	–	–	–	–	–	×
Ammovertella bulbosa G. & T.	×	–	×	–	–	⊗
LITUOLIDAE						
Ammobaculites chappelensis, n. sp.	×	×	⊗	–	–	×
Ammobaculites leptos G. & T.	×	×	×	×	–	⊗
Ammobaculites pyriformis G. & T.	×	×	×	–	–	⊗

⊗ Designates that holotype is from this formation and locality.



TEXT-FIG. 3—Arenaceous Foraminifera from the Welden limestone of southern Oklahoma.
1–4—Hyperammina rockfordensis Gutschick & Treckman.
5,6—Hyperammina gracilenta Gutschick & Treckman. *5*, Holotype, megalospheric form; *6*, microspheric(?) form.

Saccammina ligula, n. sp., *Hyperammina gracilenta* Gutschick & Treckman, *Ammobaculites chappelensis*, n. sp., *Pseudastrorhiza conica*, n. sp., *Ammobaculites leptos* Gutschick & Treckman, *Hyperammina constricta* Gutschick & Treckman, and the tolypamminids. Most specimens are well developed robust individuals with relatively thick-walled tests. The preservation is good except for some distortion of the test by compaction.

The Chappel fauna is characterized by great numbers of *Hyperammina constricta* Gutschick & Treckman, *Ammobaculites chappelensis*, n. sp., and *Thurammina congesta*, n. sp. The next group of common specimens includes *Hyperammina conica*, n. sp., *Thurammina pustulosa*, n. sp., and *Thurammina tubulata* Moreman, Preservation is generally good, but the conspicuous characteristic of all specimens is their thin delicate wall structure. As a result, the inflated and tubular specimens tend to become broken and fragmented.

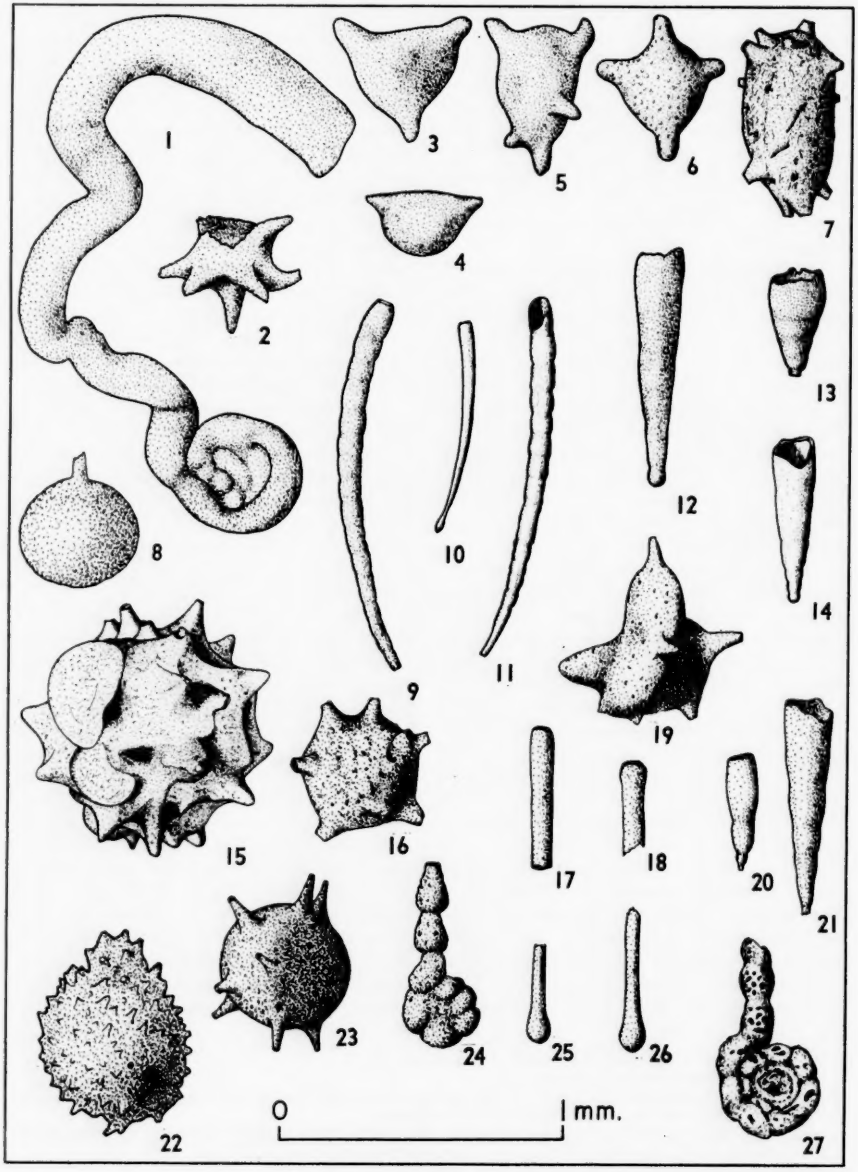
The basal Lodgepole limestone fauna consists mostly of abundant *Pseudastrorhiza digitata*, n. sp., *Sorosphaera geometrica* Eisenack, and *Trepeilopsis glomospiroides* Gutschick & Treckman. *Pseudastrorhiza lanceola*, n. sp., and *Pseudastrorhiza baccula*, n. sp., are less abundant but common. The middle Lodgepole fauna has an abundance of *Hyperammina kentuckyensis* Conkin and *Reophax calathus*, n. sp. Preservation is generally good in the Lodgepole, and the most common specimens have well-developed fairly thick-walled tests.

An analysis of the distribution of species and individuals among the families of Foraminifera brings out the following observations. The astrorhizids, particularly the genus *Pseudastrorhiza*, are an important element of early Mississippian faunas. They are especially common in the basal Lodgepole, Rockford, and Welden limestones. The saccamminids occupy an important place in these faunas, represented by the genera *Thurammina*, which is quite diverse, *Lagenammina*, *Sorosphaera* and *Saccammina*. Specimens of this family are common in the Rockford, Welden and Chappel, but they have not been found in the Lodgepole except for *Sorosphaera*. Hyperamminids have had an explosive evolution in early Mississippian time as is indicated by the large number of unique species in the Rockford, Welden, and Chappel limestones. They are also common in the middle portion of the Lodgepole limestone. They are common in the Sappington formation, Louisiana limestone, and Upper Rockford shale.

The reophacids are present in the Rockford and Lodgepole limestones, but there in no common species. They have not been recognized in the Welden or Chappel limestones. The tolypamminids are a significant group with great numbers and diversity of specimens in the Rockford limestone. However, except for *Tolypammina*, *Ammovertella*, and the lone occurrence of *Trepeilopsis* in the basal Lodgepole limestone, they appear to be absent in the Welden and Chappel limestones. *Tolypammina* appears to be a fairly common widespread genus. Although specimens of it are in the Lodgepole limestone, there are many in the underlying Sappington of the same area. With the exception of the Lodgepole, *Ammobaculites* is well represented in the faunas by abundant individuals of several species.

In summary, the following genera are listed in the order of their importance in the five faunas: *Hyperammina*, *Tolypammina*, *Ammobaculites*, *Thurammina*, and *Pseudastrorhiza*. The faunas are sufficiently distinct so that the assemblage for each may be useful for recognition of the formation.

7—*Hyperammina constricta* Gutschick & Treckman.
8—*Lagenammina sphaerica* Moreman.
9–12—*Hyperammina conica* n. sp. *9*, Megalospheric form; *10–12*, microspheric forms; *11*, holotype.
13,23(?)—*Thurammina furcata* Gutschick & Treckman.
14,18–22—*Saccammina ligula* n. sp. *14,21–22*, Sieve-like forms in which acid has removed calcareous (?) material; *18–20*, three views of complete well-preserved specimen.
15,16—*Tolypammina cyclops* Gutschick & Treckman.
17,24—*Pseudastrorhiza conica* n. sp. *17*, Holotype from locality 2; *24*, paratype.
25—*Ammobaculites chappelensis* n. sp.
26—*Ammobaculites leptos* Gutschick & Treckman.
27,28—*Ammobaculites pyriformis* Gutschick & Treckman.



TEXT-FIG. 4—Arenaceous Foraminifera from the Chappel limestone of central Texas.
1—Tolypammina rotula Gutschick & Treckman.
2—Pseudastrorhiza delicata Gutschick & Treckman.
3–7,16—Thurammina congesta n. sp. *3*, Trigonal paratype; *4*, paratype with two projections; *5*,

PALEOECOLOGY

It is difficult to evaluate the paleoecological implications of the faunas. Based upon established correlations, the faunas are all closely related in age and components. However, they are each separated from the others by hundreds of miles. For example, the Welden outcrop area is seaparated from that of the Chappel outcrop by about 300 miles, both of these outcrops from the Rockford outcrop by about 750 miles, and the Weldon outcrop from the Lodgepole outcrop by 1100 miles. The Chappel outcrop is some 950 miles from the Rockford outcrop and 1300 miles from the Lodgepole outcrop. About 1400 miles separate the Rockford and Lodgepole areas. This fact would permit only gross generalizations.

Arenaceous Foraminifera are extremely abundant in Lower Mississippian rocks, and the faunas are composed of many genera and species. They must surely be controlled by the conditions of their respective environments. More detailed studies will have to be made before the relationships can be understood.

CONCLUSIONS

The primary purpose of this study is to call attention to the remarkable widespread occurrence of the early Mississippian arenaceous Foraminifera, to classify the fauna for subsequent systematic detailed studies, to present some of the problems in making an evaluation of the widely separated (geographic) faunas, and to make observations concerning the phylogeny and general paleoecology.

There is ample justification for employing the acid recovery techniques to obtain faunas which otherwise would go unnoticed or have small value. Specimens washed from shales are often distorted due to compaction which makes it hard to recognize and identify them, whereas those from the limestones are usually uncompressed. Ireland (1956) has also given good reasons in support of the procedure.

SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERA

Family ASTRORHIZIDAE Brady

Genus PSEUDASTRORHIZA Eisenack

This genus is characterized by a free test with a central chamber and several radiating arms or projections in varying planes. The test wall is thin and is composed of fine sand grains. Apertures are not apparent. There is a close relationship between *Pseudastrorhiza* and *Thurammina* of the family Saccamminidae. Eisenack (1932, 1955) originally placed *Pseudastrorhiza* in the Saccamminidae. *Thurammina* has a free nearly spherical test which has nipple-like protuberances with apertures on their ends. Specimens in the Lower Mississippian faunas range from spherical forms with few short projections to specimens with many long arms. These are generally not difficult to assign to either genus, but specimens which are transitional create a taxonomic problem. The basic difference between the two genera is in the presence or absence of arms and apertures. The apertures are not apparent in our specimens.

PSEUDASTRORHIZA BACCULA, n. sp.

Pl. 147, figs. 5,6,9; Text-fig. 5—9

The test of this small form is free and consists of a central cavity and many short stubby divergent projections. The central chamber is more or less equidimensional but very irregular in surface detail. This is

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holotype; *6*, quadri-radiate paratype; *7,16*, paratypes.
8—*Lagenammina sphaerica* Moreman.
9–11—*Hyperammina constricta* Gutschick & Treckman.
12–14,20,21—*Hyperammina conica* n. sp. *12,14*, Megalospheric specimens; *13,20,21*, microspheric specimens.
15—*Thurammina arenacorna* n. sp. Holotype showing large rounded quartz grains studded in test.
17,18,25,26—*Hyperammina rockfordensis* Gutschick & Treckman.
19—Unidentified single specimen from the Chappel limestone of locality 3.
22—*Thurammina pustulosa* n. sp. Holotype shows sac-like projection at top.
23—*Thurammina tubulata* Moreman.
24—*Ammobaculites pyriformis* Gutschick & Treckman.
27—*Ammobaculites chappelensis* n. sp. Holotype.

probably due to the number, random distribution, and orientation of the tubules that radiate outward from its surface. The projections are short cones which are either pointed or rounded at their tips and number about 15 to 20 for each specimen. The apertures are not apparent. The test is made up of coarse silt-size quartz grains which are fairly well cemented together.

Measurements of the types in millimeters are as follows:

	Pl. 147 figs. 5,6 Holotype	Text-fig. 5—9 Paratype
Greatest diameter	0.60	0.44
Maximum length of projections	0.10	0.07
Number of projections	25	20

This species is based upon 10 specimens in the collection from the basal part of the Lodgepole limestone collected at locality 4.

This small form with its equidimensional size and irregular shape is not only uncommon in the samples of the lower Lodgepole; it is inconspicuous as well. It is characterized by its compact form and large number of very short projections. It is these features which distinguish it from all other described species of this genus. It was given the specific name because of its resemblance to a small berry.

PSEUDASTRORHIZA CONICA, n. sp.

Pl. 148, figs. 7,14,15,18; Text-fig. 3—17,24

Thuramminoides? sp. GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 234, pl. 33, fig. 25.

The test is free consisting of a central chamber from which conical projections radiate outward. The central part of the test is irregularly subglobular to polygonal, although in most specimens it is distorted due to compaction. The projections are acutely conical, being more slender in the less mature tests and stouter with wider base in the mature specimens. Projections number from 6 to more than 15 and are scattered in random fashion over the central chamber. The test wall is composed principally of coarse silt-sized quartz with some fine sand-sized grains only moderately cemented together leaving a granular surface. The color of the test is white.

Measurements in millimeters of typical mature specimens are given at top of next page.

Some 20 or more specimens have been studied from the Welden limestone of Oklahoma, and it is recognized in the Rockford limestone of northern Indiana.

Remarks.—As mentioned previously, there is little distinction between some species of *Pseudastrordiza* and *Thurammina* in early Mississippian faunas. This species

EXPLANATION OF PLATE 147

All illustrations on this plate are unretouched photographs and are magnified ×50.

FIGS. *1,4,7,10—Pseudastrorhiza digitata*, n. sp. *1,4*, Two photos of holotype with and without alcohol-glycerin surface; and *7,10*, two photos of paratype showing bifurcate ray extensions. Both specimens are from the basal Lodgepole limestone of locality 4.

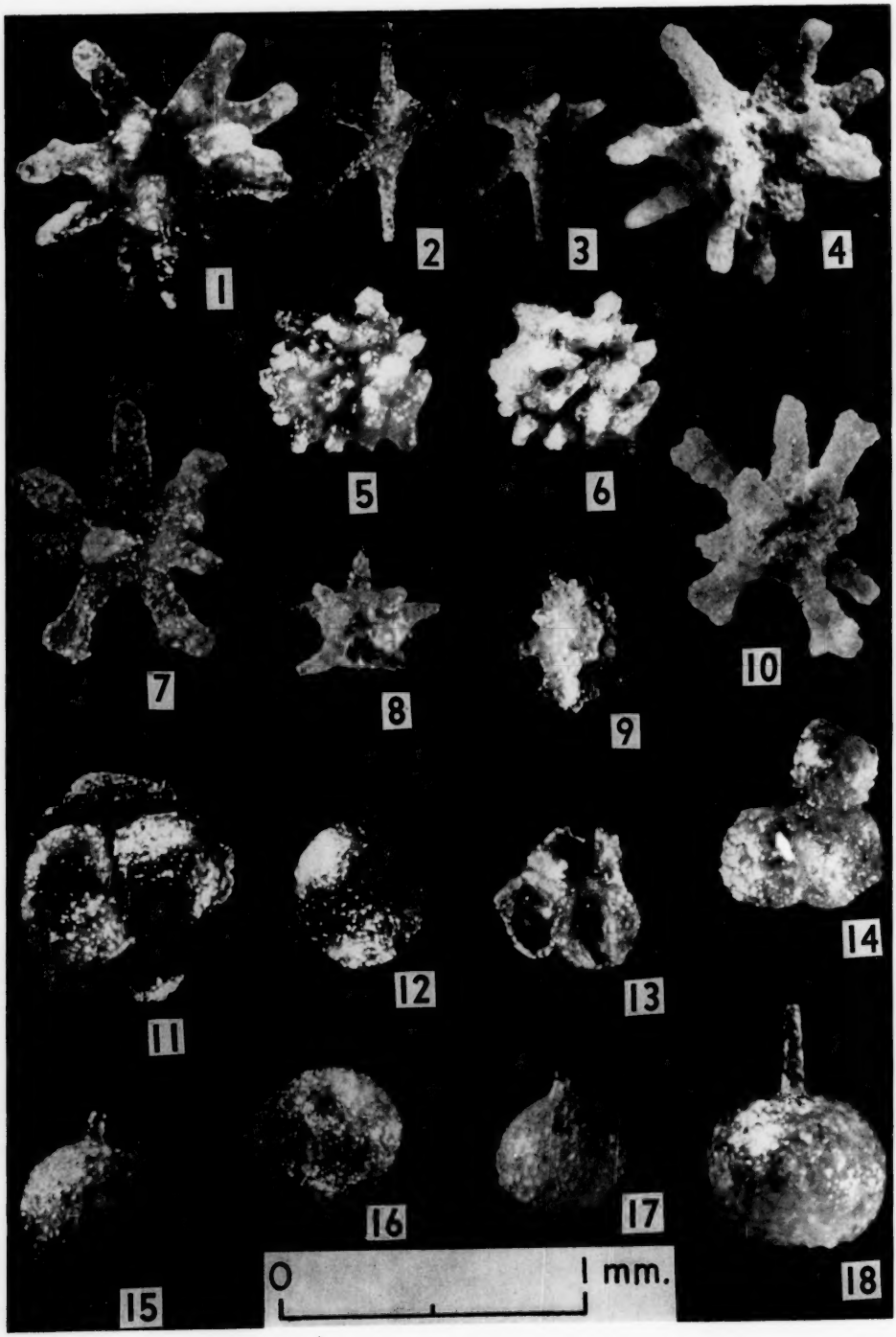
2,3—Pseudastrorhiza lanceola, n. sp. Two photos of holotype with and without alcohol-glycerin surface. Specimen is from the basal Lodgepole limestone of locality 4.

5,6,9—Pseudastrorhiza baccula, n. sp. *5,6*, Two photos of holotype with and without alcohol-glycerin surface; and *9*, paratype. Both specimens are from the basal Lodgepole limestone of locality 4.

8—Pseudastrorhiza delicata Gutschick & Treckman. Incomplete specimen from the Chappel limestone of locality 3.

11–14,16—Sorosphaera geometrica Eisenack. *11*, Two-chambered form inside brachiopod shell; *12,16*, single-chambered tests; and *13,14*, three-chambered form. All specimens are from the basal Lodgepole limestone of locality 4.

15,17,18—Lagenammina sphaerica Moreman. *15,18*, Two specimens from the Welden limestone the latter being unusually large and complete; and *17*, small broken specimen from the Chappel limestone of locality 3.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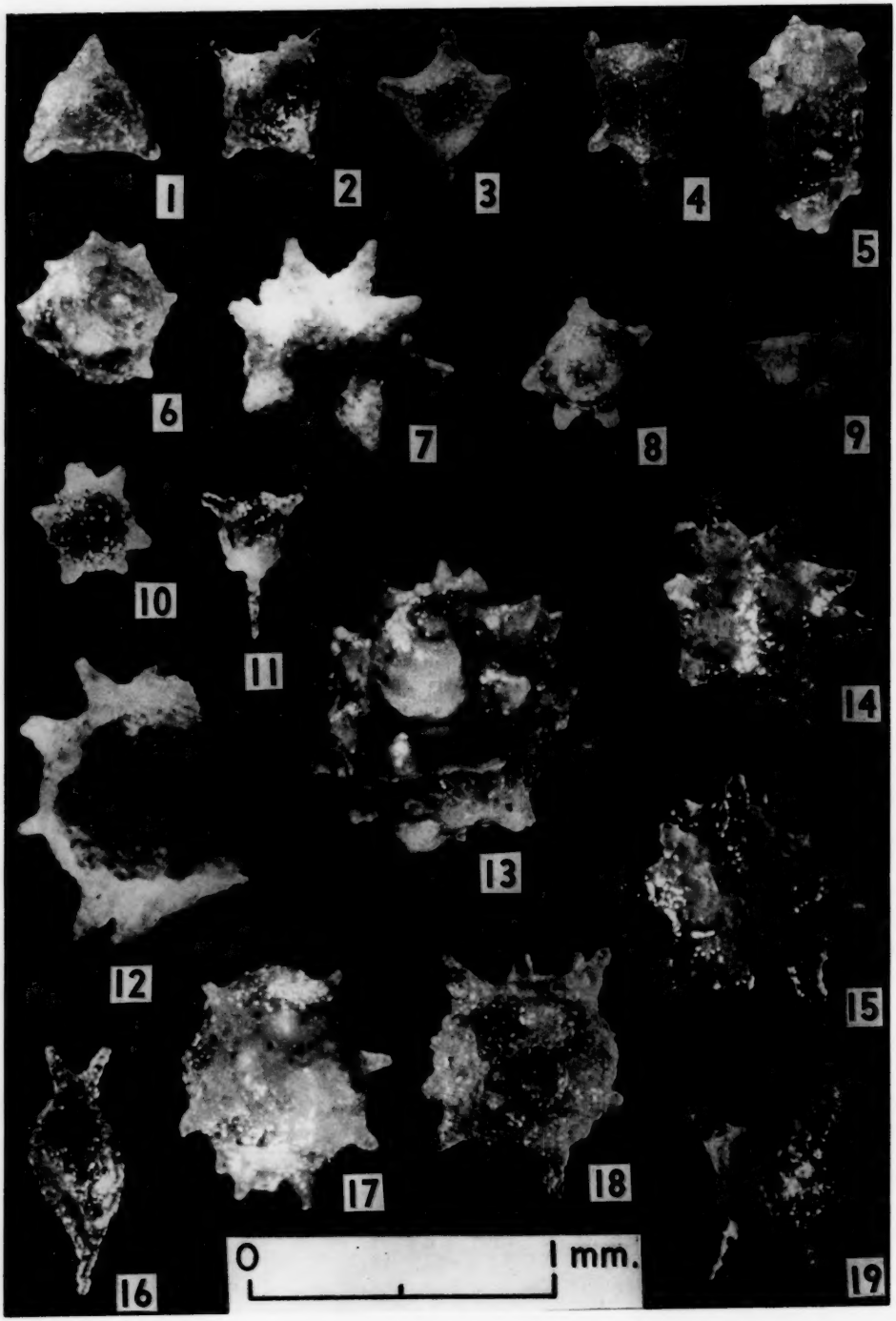
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	Pl. 148, figs. 7,14 Text-fig. 3—17 Holotype	Pl. 148, fig. 15 Text-fig. 3—24 Paratype	Unfigured specimen	Rockford specimen
Maximum diameter	0.80	0.86	0.96	0.80
Length of projections	0.20	0.20	0.20	0.15
Diameter at base of projections	0.15	0.16	0.17	0.11
Number of projections	11+	18	19	18+

seems to be intermediate between the two genera but was placed in the former because of the numerous fairly elongate projections. It resembles both *Pseudastrorhiza delicata* Gutschick & Treckman, 1959, from the Rockford limestone of northern Indiana and *Pseudastrorhiza digitata*, n. sp., from the Lodgepole limestone of Montana. However, it has conical rather than tubular projections. Specimens also resemble *Pseudastrorhiza irregularis* Dunn and *Pseudastrorhiza regularis* Dunn, 1942, from the Lower Silurian of Illinois, but differ in the greater size and number of projections.

PSEUDASTRORHIZA DIGITATA, n. sp.
Pl. 147, figs. 1,4,7,10; Text-fig. 5—1,2

The test of this most common Lodgepole astrorhizid is free and consists of a central chamber from which numerous tubular finger-like projections radiate. The central chamber is relatively small compared to the size of the entire test and is quite irregular in shape. In most specimens this chamber is flattened and has little volume. The number of digitate projections varies from as few as 5 or 6 for the smaller specimens to as many as 18 for the large more mature specimens. The greater percentage of specimens have from 10 to 14 rays. The projections have no regular spatial arrangement. They radiate out in all directions in various planes, and this is typical of the genus. Each tubule is finger-shaped, tapering gradually from a relatively wide base where it joins the central capsule to a small rounded point at its outer extremity. The rays in a single specimen are not all of the same length but vary up to almost one-half the diameter of the test. In some specimens the tubes are circular to elliptical in cross-section, but in most specimens they are flattened either naturally or by compaction. About 5 to 10 percent of the specimens have bifurcating tubules where the bifurcations may start near the base or out at the tip of the ray. A specimen may have up to 4 or 5 rays which do this particularly at their tips where they become heart-shaped. The test wall is fairly rigid and firm and is composed of well-cemented granular silt-size quartz grains. Apertures are not apparent. Specimens are light brownish gray in color.

Measurements in millimeters are given at top of next page for two typical mature specimens selected from over 80 specimens in the collection.

EXPLANATION OF PLATE 148

All illustrations on this plate are unretouched photographs and are magnified ×50.

FIGS. *1–5,8–10—Thurammina congesta*, n. sp. *1–3,5,8–10*, Variants of the species; and *4*, holotype. All specimens are from the Chappel limestone of locality 3.

6—Thurammina echinata Dunn. Chappel limestone from locality 3.

7,14,15,18—Pseudastrorhiza conica, n. sp. *7,14*, Holotype photographed without and with glycerin from the Welden limestone of locality 2; *15*, paratype from the Welden limestone.

11—Thurammina triradiata Gutschick & Treckman.

12,17—Thurammina tubulata Moreman. Interior and exterior views of specimen from the Chappel limestone of locality 3.

13—Thurammina arenacorna, n. sp. Holotype from the Chappel limestone of locality 3.

16—Pseudastrorhiza lanceola, n. sp. Unusually distorted specimen from the Lodgepole limestone of locality 4.

19—Thurammina furcata Gutschick & Treckman? Specimen has much stouter projections than type specimen; from the Welden limestone of locality 1.

	Pl. 147, figs. 1,4 Holotype	Paratype
Maximum diameter	1.00	1.00
Maximum length of projections	0.34	0.35
Diameter of central portion	0.35–0.45	0.40
Number of radiating tubules	17	12
Diameter of tubules at their base	0.14	0.18
Median diameter of tubules	0.12	0.13

Thickness of the wall in this species is from 0.025–0.030 mm. All specimens in the collection come from locality 4 and were collected from the basal (lower 10 feet) part of the Lodgepole limestone where they are very common.

Remarks.—The species is characterized by its large size, robust test, irregular central capsule, and numerous finger-like projections as the specific name implies. It resembles the Rockford form *Pseudastrorhiza delicata* Gutschick & Treckman, but differs from it in being larger, more robust, and having stouter and more numerous rays. There are Silurian species which are similar, but the differences are so marked that no comparison is made with them. This species stands out as unique in Mississippian faunas and is based upon numerous well-preserved complete specimens.

PSEUDASTRORHIZA LANCEOLA, n. sp.
Pl. 147, figs. 2,3; Text-fig. 5—7,8

This small simple astrorhizid has a free test which consists of a central chamber from which few spire-shaped projections radiate. The central capsule is small and varies in shape depending upon the number and spatial arrangement of the rays. It is usually polygonal in outline, but in a few specimens it is globular. The stick-like extensions are long tapering pointed tubules which vary in number from four to six. They project outward in various planes in a heterogeneous arrangement. Occasionally opposite pairs of rays line up to give adjacent pairs a slightly oblique cruciform appearance. The test wall is composed of fine silt-sized quartz grains fairly well cemented, but the skeleton is fragile due to the thinness of the wall. No apertures are apparent on the delicate tips of the rays.

Measurements in millimeters of the two figured specimens are given below.

	Pl. 147, figs. 2,3 Holotype	Text-fig. 5—7 Paratype
Maximum diameter	0.71	0.67
Diameter of central chamber	0.18–0.24	0.26
Maximum length of rays	0.23	0.23
Diameter at the base of the rays	0.07	0.07
Median diameter of the rays	0.04–0.05	0.05
Number of rays	6	6

The thickness of test wall is about 0.010 mm. This new species is based upon 15 fairly well-preserved specimens recovered from acid residues of the basal Lodgepole beds at locality 4. One or two specimens from the Welden limestone are placed in this species.

Remarks.—This species can be recognized by its angular appearance, small size, long tapering pointed stick-like rays and very finely granular test. It differs markedly from *Pseudastrorhiza delicata* Gutschick & Treckman from the Rockford limestone of Indiana, and *Pseudastrorhiza digitata*, n. sp. with which it is found in having fewer and more spire-like pointed rays. It does not have the regular arrangement of rays and coarseness of test grain size as *Pseudastrorhiza regularis* Dunn. The specific name refers to the small light spear-shaped rays.

PSEUDASTRORHIZA DELICATA Gutschick & Treckman
Pl. 147, fig. 8; Text-fig. 4—2

Pseudastrorhiza delicata GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 231, pl. 33, figs. 1–5.

Several fragmental specimens of this species were found in the Chappel limestone of locality 3. They are almost identical in

size and general characteristics to the type specimens, although they are not complete. One of the better specimens illustrated by figure 8 on Plate 147 has seven projections which is fewer than on the type specimens. It may have contained more when entire. Its scarceness may be due in part to the fragile nature of the test which is susceptible to destruction. To some extent this was also true for specimens in the Rockford limestone. There are several questionable specimens from the basal Lodgepole limestone and the top layer of the Welden limestone. They are generally incomplete and deformed.

The types are from the Rockford limestone of northern Indiana.

Family SACCAMMINIDAE Cushman
Genus SOROSPHAERA H. B. Brady
SOROSPHAERA GEOMETRICA Eisenack
Pl. 147, figs. 11–14,16

Sorosphaera geometrica EISENACK, 1954, Senckenbergiana Lethaea, Frankfurt am Main, v. 35, no. 1–2, p. 61, pl. 4, figs. 19,20, pl. 5, figs. 2–6; text-fig. 1.

About 40 or more specimens were recovered from the Lodgepole limestone. They have a single subspherical chamber or they consist of two, three, or possibly four globular chambers joined together. The variation of one, two, three, or more chambered tests appears to be closely related as indicated by color, wall texture, size and shape of chambers, and association. They correspond closely to Eisenack's analysis and illustrations of *Sorosphaera geometrica* and have been identified as this species. All appear to have been attached either loosely or firmly to some object although only two specimens, both two-chambered tests, are still attached to the inside of a brachiopod shell fragment which is preserved because it has been silicified. All specimens are some shade of grayish brown.

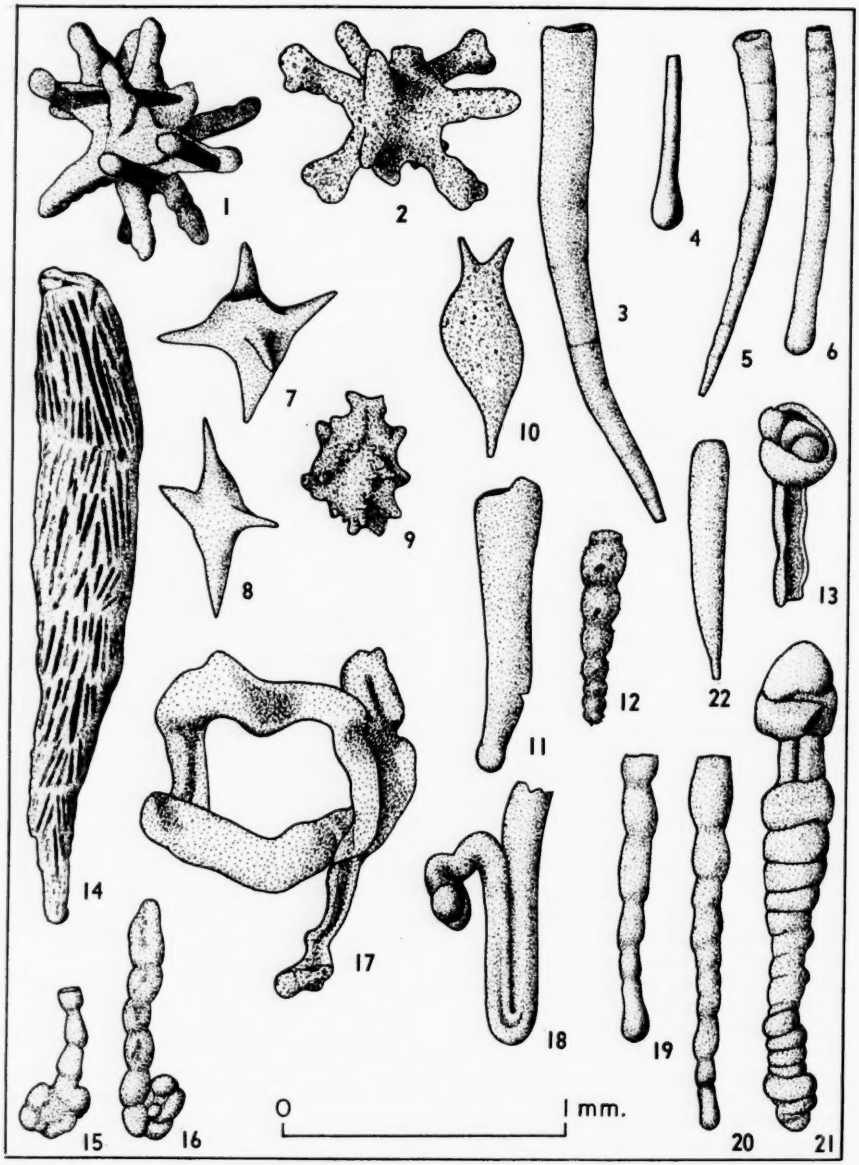
The single chambered specimen forms, of which there are about 20 specimens, are subspherical and resemble *Psammosphaera cava* Moreman, 1930. Close inspection shows that many of them have a slightly flattened surface which may represent the contour of the surface of attachment, although the tests are globular and complete. A number of these single-chambered specimens have a pair of shallow dimples (Pl. 147, fig. 16) with openings that suggest apertures. These are regarded as secondary features due perhaps to compression by compaction. There are some specimens that show little evidence of attachment, and they may have been free.

Ten of the specimens are double chambered as in Plate 147, figure 11, which shows the combination firmly attached to the inside of a brachiopod valve. The chambers are globular, but they tend to be modified by the contour of the surface of attachment. This side is usually smooth and curved as is common in the interior of brachiopod shells. Several of the specimens have the chambers completely deflated on the free side, yet the surface of attachment is smooth curved and unaffected. If the compaction took place diagenetically, one would also expect the surface of attachment to be flattened. The compressed forms have a prominent rim around the outer border of both chambers. The double combination resemble *Sorosphaera bicella* Dunn, 1942, but they are not spherical chambered nor are the tests free.

The remainder of the specimens are three-chambered combinations. However, a single specimen was found with possibly four chambers, but it is badly compressed. These specimens are similar to the others in that they have also been attached, and a number of them are compressed and distorted and have deflated chambers. The three-chambered specimens resemble *Sorosphaera tricella* Moreman, 1930. However, they do not have spherical chambers and they are not free.

The average diameter of mature specimens of single-chambered specimens is 0.32 mm. The wall is formed of coarse silt to fine quartz grains that are firmly cemented with silica to form a rigid test. The wall thickness is about 0.03 mm.

It is much more likely that the above specimens represent various manifestations of a single species, such as Eisenack determined for the Silurian forms of Gotland. The Lodgepole specimens have the characteristics including the pattern of chamber junctures typical of this species. These specimens differ quite markedly from *Sorosphaera papilla* Gutschick & Treckman, 1959, in that they lack papillae and generally have fewer chambers. There are many spherical to globular tests in the Welden residues, but



TEXT-FIG. 5—Arenaceous Foraminifera from part of the Lodgepole limestone of southwestern Montana.

1,2—Pseudastrorhiza digitata n. sp. *1*, Holotype; *2*, paratype. Locality 4.

3–5,22—Hyperammina kentuckyensis Conkin. Locality 5.

these are lagenamminids with the slender necks broken off. Otherwise, the species is not represented in the Chappel and Welden limestones.

The types are from the Middle Silurian of Gotland (Baltic).

Genus SACCAMMINA M. Sars

SACCAMMINA LIGULA, n. sp.

Pl. 150, figs. 3,6,8,11; Text-figs. 3—14,18–22

The test is attached and consists of a hemispherical shell with neck-like extension and a small semicircular aperture. The surface to which this form is attached makes up the floor of the test, and it controls the contour of the periphery. The chamber is hemispherical except for the neck which extends radially. The neck is somewhat semicylindrical and has a semicircular aperture at its terminus. The test is composed of coarse silt-size quartz grains and possibly calcareous grains as well. Some specimens are entirely quartz while others are porous where organic shell fragments have been dissolved from among the quartz fabric. There are many specimens which have a basic shape like the holotype, but the test is cage-like and skeletal in appearance. The common pattern is tetrameral. The shape is typical of the species, but the four elliptical areas in tetrahedral arrangement are missing. This leaves gaps or openings in the test. The skeletal portion is fairly rigid and corresponds in some degree to the edges of a tetrahedron. Actually, the test is not angular as implied but conforms to the shape of a hemisphere with extension for the aperture. In a few others, all that remains is a circular rim with an apertural neck. All of these specimens are included in the species because of their similarity and association.

Measurements in millimeters of typical specimens are given below. The wall thickness varies from 0.025–0.030 mm.

All varieties of this species are common in the Welden limestone of Oklahoma where over 50 specimens were selected for study. The cage-like specimens have been recognized in the Chappel limestone and from the upper Rockford shale of southern Indiana. None has been found in the Lodgepole or Rockford limestones, but the species is small and easy to overlook.

Remarks.—We have not come across any other species of this size, shape, and composition which are attached and with which a comparison can be made. Stratigraphically the closest related form is *Proteonina pseudospiralis* Cushman & Stainbrook, 1943, from the Upper Devonian Independence shale of Iowa. This species is free and the apertural neck is at one side of the test, giving it a spiral appearance.

Genus LAGENAMMINA Rhumbler

LAGENAMMINA SPHAERICA Moreman

Pl. 147, figs. 15,17,18; Text-figs. 3—8,4—8

Lagenammina sphaerica MOREMAN, 1930, Jour. Paleontology, v. 4, p. 51, pl. 5, fig. 15. GUT-

	Pl. 150, fig. 11 Holotype	Text-fig. 3—14	Text-fig. 3—21	Text-fig. 3—22
Length of test	0.40	0.38	0.46	0.44
Width or diameter	0.25	0.27	0.27	0.34
Height of test	0.15	0.14	—	—
Width of neck	0.09	0.08	0.09	0.08

6—Hyperammina rockfordensis Gutschick & Treckman? Locality 5.
7,8,10—Pseudastrorhiza lanceola n. sp. Locality 4.
9—Pseudastrorhiza baccula n. sp. Locality 4.
11—Tolypammina sp.
12—Reophax sp.
13,21—Trepeilopsis glomospiroides Gutschick & Treckman. Locality 4.
14—Reophax calathus n. sp. Holotype from locality 5.
15,16—Ammobaculites leptos Gutschick & Treckman. Locality 4.
17—Tolypammina sp.
18—Tolypammina sp.
19,20—Reophax lachrymosa Gutschick & Treckman?

SCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 233, pl. 33, fig. 14.

This simple saccamminid is very common in the Welden limestone residues, rare in the Chappel limestone, and has not been found in the Lodgepole limestone. A single small well-preserved specimen was described from the Rockford limestone of Indiana. Over 50 well-preserved specimens were recovered from the Welden. They are spherical with a relatively long single extension. Many of the tests are slightly distorted and have the projections broken off. The test is composed of subrounded coarse silt-size quartz grains which are well-cemented together by silica to make a fairly rigid test. The wall thickness in the individual test varies from 0.025 to 0.050 mm. Measurements of a large complete oblate specimen are as follows: total length, 0.75 mm.; diameter, 0.48 to 0.58 mm.; length of projection, 0.28 mm.; diameter of projection at base, 0.075 mm.; apertural end diameter, 0.05 mm. Two spherical specimens were found in the Chappel limestone with the necks partly broken off. They have a diameter of 0.41 mm.

There are a number of species in this genus which are very similar. The Welden and Chappel forms do not fit any of them perfectly but come closest to the species to which they are assigned. They do not have the coarseness of grain size of *Lagenammina sphaerica* Moreman. Otherwise, they agree in size and shape. They differ from *Lagenammina bulbosa* Dunn, 1942, in having finer grain size and longer necks, although the neck in the Silurian form may be broken off. The large Welden specimens approach the size of *Lagenammina cucurbita* Moreman, 1933, but they have a longer more slender neck than the latter. The type specimen is from the lower Silurian Chimney Hill limestone from the Arbuckle Mountains, Oklahoma.

Genus THURAMMINA H. B. Brady

THURAMMINA ARENACORNA, n. sp.

Pl. 148, fig. 13; Text-fig. 4—15

The test is free and consists of a spherical central chamber with numerous short conical nipple-like projections which radiate outward. It is composed of coarse quartz grains. The central chamber is well formed and large. Its entire surface is covered with short conical protuberances or papillae, superficially resembling the fruit of the sweetgum tree. The projections are short and conical with sharp tips. Apertures are not apparent on the tips of the papillae. The wall is relatively thin. Specimens are generally found in the coarse microfraction.

The test wall consists principally of quartz grains with a moderate amount of cement and numerous fine to medium-size well rounded and frosted or etched quartz grains scattered over its granular surface. The larger grains are in sharp contrast to the groundmass of the test and are an important characteristic of the species.

Dimensions in millimeters of the holotype are as follows: maximum diameter 1.00; length of projections 0.17; diameter at base of projections 0.18; maximum diameter of largest quartz grains 0.45; number of projections 20–22. The species has been found only in the Chappel limestone of Central Texas where it is rare.

Remarks.—This species was placed in *Thurammina* because of its spherical shape and short nipple-like protuberances. It closely resembles *Pseudastrorhiza conica*, n. sp., from the Welden but was not included in this form because of its more spherical chamber, shorter projections, and the scattered quartz grains in its test. It also resembles the Recent form *Thurammina papillata* Brady var. *castanea* Heron-Allen & Earland. It closely resembles *Thurammina echinata* Dunn from the Silurian of Tennessee, Illinois, and Missouri but this latter form lacks the quartz grains in the test and is not as large.

The specific name implies sand thistle or bur after the numerous radiating pointed projections and the scattered quartz grains which stud the surface of the test.

THURAMMINA CONGESTA n. sp.

Pl. 148, figs. 1–5,8–10; Text-fig. 4—3,4,5,6,7,16.

This species presents a problem in taxonomy. Individual single-chambered tests of great variation in shape are associated in loosely to tightly packed clusters. These apparently represent the cavity fill such as might form in a brachiopod or mollusc shell. The tests which occur singly in Chappel

limestone acid residues are unique. Single tests vary from globular, spherical, ellipsoidal, polygonal, to irregular in shape, and they have tuberculate surfaces. Short blunt uniform-size tubular projections, varying in number from two to twelve or more, are distributed over the surface either in regular patterns or in random arrangements. The short tubules may be cylindrical with circular terminal aperture or they may have a smoothly rounded tip without apparent aperture. Possibly the former are the result of the latter having the tips broken off.

The test is made of silt grains of quartz cemented to form a smooth surface. The test is thin and moderately weak. Individuals are bound together in clusters by a few points of weak contact. Clusters break apart readily in the samples, resulting in few aggregates and numerous individual tests. Groups of two to six individuals are common. Shapes and number of tubules for individuals within a single cluster vary, and the shapes of the clusters conform to the surface contour of the cavity in which they grew.

Measurements in millimeters of a few individual tests illustrated on Plate 148 and on Text-figure 4 are given below:

Plate 148 Text-fig.	fig. 9 4—4	fig. 1 4—3	fig. 3 4—6	fig. 4 4—5	fig. 5 4—7
Maximum diameter	0.40	0.45	0.50	0.53	0.70
Diameter of chamber	0.24×0.28	0.32	0.30	0.38×0.29	
Shape of test	bilateral	trigonal	quadrate	irregular	irregular
Number of tubules	2	3	4	5	9
Diameter of tubules	0.055	0.075	0.15	0.075	0.06
Length of tubules	0.06	0.10	0.10	0.09	0.075

There is evidence that individual tests have grown together in openings or cavities. They may have been independent of each other. This crowding together in enclosures of varying sizes and shapes and the necessity for the apertures to form in confined spaces accounts for the multitude of shapes and the variability in the number of apertural projections. The individuals whose shape is most common and regular were probably in the central part of the enclosure. The irregular and anomalous types were probably crowded in and around the edges and irregularities within the cavity. As a result, there are many one-of-a-kind specimens.

More than ten specimens of the bi-spinose form were found, and these closely resemble *Thurammina elliptica* Moreman, 1930, from the Silurian of Oklahoma and *Ordovicina oligostoma* Eisenack, 1937, from the Silurian of the Baltic area.

Ten or more specimens of the tri-tuberculate form with apertures resemble *Thurammina* aff. *T. trituba* Eisenack, 1954, from the Baltic Silurian, and *Thurammina phialaeformis* Crespin, 1958, from the Permian of Australia. There are some compressed triangular specimens (Pl. 148, fig. 1) which resemble *Thekammina moremani* Dunn from the Silurian of Missouri. However, the Mississippian forms have papillate apices.

Many of the larger specimens with numerous tubules resemble *Thurammina irregularis* Moreman, 1930, and *Ordoviciana oligostoma* Eisenack. They may compare closely with *Thurammina* (*Thyrammina*) *mamillata* Franke, 1928, from the Upper Cretaceous of Germany.

THURAMMINA DIFORAMENS Ireland

Thurammina diforamens IRELAND, 1956, Jour. Paleontology, v. 30, p. 841, text-fig. 3—6,7; GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 233, pl. 33, fig. 15.

Four or five specimens occur in our samples from the Welden limestone of Oklahoma which are similar to the type specimens of *Thurammina diforamens*. The bi-spinose specimen in the Chappel identified as *Thurammina congesta*, n. sp., resembles this species, but it is smaller and has shorter projections.

The types are from the Upper Pennsylvanian of Kansas.

THURAMMINA ECHINATA Dunn
Pl. 148, fig. 6

Thurammina echinata DUNN, 1942, Jour. Paleontology, v. 33, p. 331, pl. 43, figs. 20,21,23.

There are a few specimens in the Chappel limestone which have a globular test that has numerous short small projections with terminal aperture. They are similar to *Thurammina congesta*, n. sp., with which they are associated, but the spines are more numerous, much smaller, and less prominent than in *Thurammina congesta*.

The types are from the Silurian of Missouri, Illinois, and Tennessee.

THURAMMINA FURCATA Gutschick & Treckman
Pl. 148, fig. 19; Text-fig. 3—13,23

Thurammina furcata GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 233, pl. 33, figs. 19–21.

Three or four specimens from the Welden limestone are placed in this species. The specimen illustrated by Text-figure 3—23 has the characteristic shape of this species, but the tubules are more robust with a greater diameter at their base than in the type specimens.

The types are from the Rockford limestone of northern Indiana.

THURAMMINA PUSTULOSA, n. sp.
Text-fig. 4—22

The test of *Thurammina pustulosa* appears to be free, globular, and irregularly inflated, with numerous short projections over its surface. The surface of the test is granular and is covered with short granular papillae. Part of the test surface is smooth. The projections are uniform in size and shape, but they are relatively small compared to the size of the quartz grains. The grain cluster gives them a rough granular appearance. There are 10 to more than 50 papillae on the holotype. Some papillae seem to have apertures at their tips.

The test wall is thin and fragile and consists of weakly cemented silt-size quartz grains. Most specimens are partly broken. Dimensions of two specimens in millimeters are:

EXPLANATION OF PLATE 149

All illustrations on this plate are unretouched photographs and are magnified ×50.

FIGS. *1*—*Hyperammina kentuckyensis* Conkin. Well developed specimen without the proloculus from near the middle of the Lodgepole limestone of locality 5.

2—*Hyperammina rockfordensis* Gutschick & Treckman? Specimen is from near the middle of the Lodgepole limestone of locality 5.

3,4—*Hyperammina gracilenta* Gutschick & Treckman. *3*, Paratype, megalospheric test; and *4*, holotype, megalospheric test. Both specimens are from the Welden limestone of the type area.

5—*Hyperammina rockfordensis* Gutschick & Treckman. This is a fairly complete small specimen from the Welden at the type locality.

6,7—*Hyperammina constricta* Gutschick & Treckman. *6*, Small complete(?) test with proloculus; and *7*, large mature specimen without proloculus. Both specimens are from the Chappel limestone of locality 3.

8–10,15,16—*Hyperammina conica*, n. sp. *8,9*, Paratypes, megalospheric; *10*, holotype, microspheric form with proloculus missing; *15*, paratype, microspheric specimen showing the constricted aperture; and *16*, paratype, microspheric specimen with proloculus. All specimens are from the Welden limestone of the type area.

11,17—*Reophax lachrymosa* Gutschick & Treckman? *11,17*, Two fairly complete uncompressed specimens from the Lodgepole limestone of locality 5.

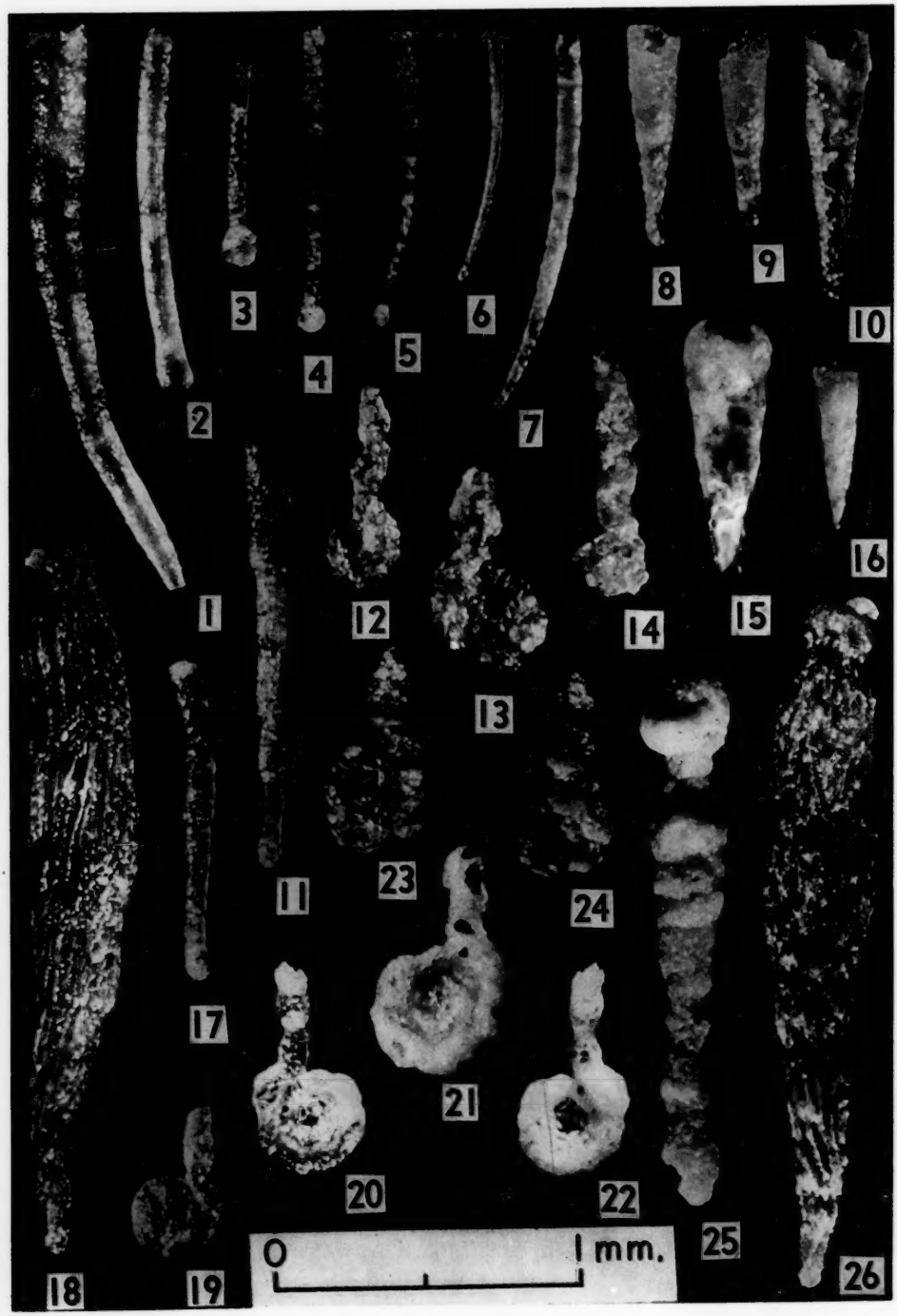
12,14—*Ammobaculites leptos* Gutschick & Treckman. *12*, Basal Lodgepole limestone, locality 4; and *14*, Welden limestone, type area.

13,23,24—*Ammobaculites pyriformis* Gutschick & Treckman. Welden limestone, type area.

18,26—*Reophax calathus*, n. sp. Two views of the large well-preserved holotype from near the middle of the Lodgepole limestone of locality 5.

19,20–22—*Ammobaculites chappelensis*, n. sp. *19*, Paratype, Welden limestone of type area; *20,21*, paratypes from the Chappel limestone, locality 3; and *22*, holotype, Chappel limestone, locality 3.

25—*Trepeilopsis glomospiroides* Gutschick & Treckman. Complete specimen from the Lodgepole limestone, locality 4.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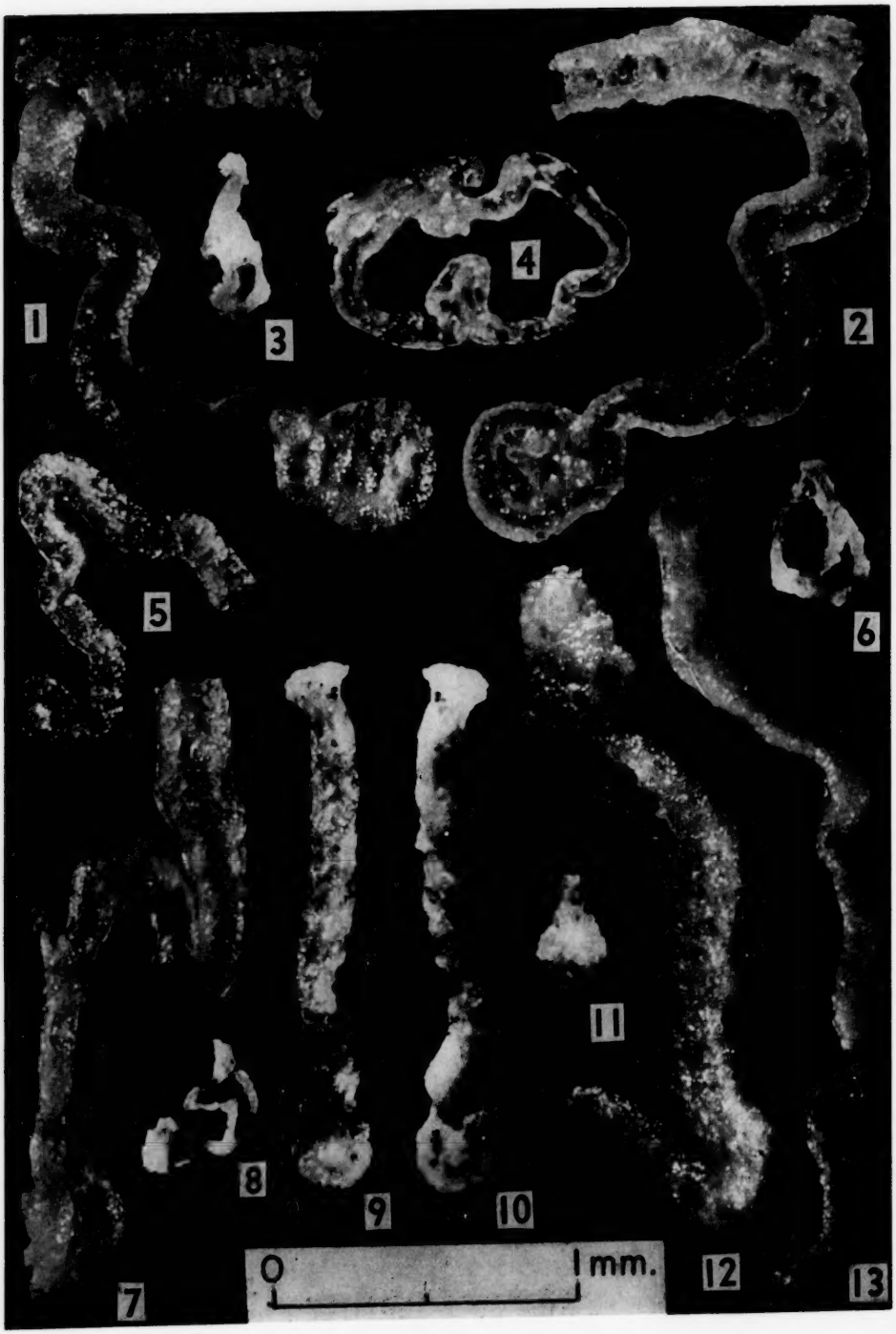
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	Text-fig. 4—22	Unfigured specimen
Maximum dimensions	0.60×0.73	0.47×0.58
Diameter of sac-like projection	0.15×0.22	0.12×0.16
Length of papillae	0.05	
Diameter of projections at base	0.04	

About 20 specimens have been collected from Chappel limestone of locality 3.

Remarks.—This species is characterized by its globular inflated test with numerous papillae giving it a pustulose surface appearance. It does not resemble any described Paleozoic forms. Some recent specimens of the varieties of *Thurammina papillata* Brady superficially resemble the Chappel form. However, they have less dense papillae.

THURAMMINA QUADRITUBULATA Dunn

Thurammina quadritubulata DUNN, 1942, Jour. Paleontology, v. 16, p. 334, pl. 43, fig. 22; GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 233, pl. 33, fig. 18.

Three or four good specimens were recovered from the Welden limestone which are recognized as this species. The Chappel specimen of *Thurammina congesta*, n. sp., Plate 148, figure 3, has the quadrate shape, but the projections are too large and rounded for this species.

The holotype is from the Middle Silurian of Missouri.

THURAMMINA TRIRADIATA Gutschick & Treckman
Pl. 148, fig. 11

Thurammina triradiata GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 233, pl. 33, figs. 16,17.

Five or more tri-radiate spherical specimens were recovered from the Welden limestone which are placed in this species. A similar species is common in the Chappel limestone, but the tubules are much shorter and more closely resemble the new species *Thurammina congesta*. A tri-radiate specimen in the Lodgepole limestone superficially resembles this species, but close study shows it to be a distorted specimen of *Pseudastrorhiza lanceola*, n. sp.

THURAMMINA TUBULATA Moreman
Pl. 148, figs. 12,17; Text-fig. 4—23

Thurammina tubulata MOREMAN, 1930, Jour. Paleontology, v. 4, p. 52, pl. 5, fig. 8.

This form is recognized in the Chappel limestone where 15 well-preserved specimens have been found. Several specimens occur in the Welden limestone. The test is spherical in shape, with numerous long tapering randomly distributed tubular projections over the surface. It is made up of silt-size subangular quartz grains with a moderate amount of silica cement.

Measurements of typical specimens in millimeters are as given at top of next page.

The Mississippian specimens are larger than the Silurian specimens, and they have longer tubules which taper to a small point. Apertures are not apparent on complete

EXPLANATION OF PLATE 150

All illustrations of this plate are unretouched photographs and are magnified ×50.

FIGS. *1,2*—*Tolypammina rotula* Gutschick & Treckman. *1,2*, Top and bottom views of specimen from the Chappel limestone, locality 3.

3,6,8,11—*Saccammina ligula*, n. sp. *3,6,8*, Cage-like varieties; and *11*, holotype. All specimens are from the Welden limestone of the type area.

4—*Ammovertella bulbosa* Gutschick & Treckman. Welden limestone, locality 3.

5,7,9,10—*Tolypammina cyclops* Gutschick & Treckman. *5*, Lodgepole specimen; *7*, coiled portion distorted by tube of attachment, Chappel limestone, locality 3; and *9,10*, two views of specimen from the Welden limestone of type area.

12—*Tolypammina sperma*, n. sp. Microspheric specimen, holotype, from the Welden limestone of type area.

13—*Tolypammina extenda* Ireland? This specimen without proloculus is from the Chappel limestone of locality 3.

	Chappel	Chappel	Chappel	Welden
Maximum diameter	0.75	0.70	0.70	0.67
Diameter of chamber	0.63	0.47	0.44	0.54
Length of tubules	0.12	0.12–0.15	0.19	0.09
Number of tubules	12+	8+	8+	10+
Wall thickness	0.020			

tubules. This common Chappel form has not been recognized in either the Lodgepole or Rockford limestones. The type specimen is from the Chimney Hill of Oklahoma.

Family HYPERAMMINIDAE Eimer & Fickert
Genus HYPERAMMINA H. B. Brady
HYPERAMMINA CONICA, n. sp.
Pl. 149, figs. 8–10,15–16; Text-figs. 3—9–12; 4—12–14,20,21

This species is especially common in the Welden and Chappel limestones but has not been recognized in our collections from the Lodgepole limestone of Montana. Over 150 specimens were recovered from Welden limestone residues and 60 or more from the Chappel limestone, which form the basis of study for this new species.

The test is free and consists of a spherical proloculus and straight uniformly expanding conical second chamber which has a constricted terminal aperture at the open end. Both megalospheric and microspheric dimorphs are preserved. The ratio of microspheric to megalospheric specimens in six to one in the Welden and one to one in the Chappel. Very few microspheric specimens have the delicate small proloculus preserved, but many megalospheric specimens have the proloculus well preserved. It tends to be spherical in the latter. The second chamber of many specimens starts close to the maximum diameter of the proloculus, eliminating sharp separation between the two chambers. The proloculus in the few microspheric specimens that have it preserved as spherical and well separated from the second chamber.

The second chamber characterizes the species. It expands gradually and evenly to produce a narrow sharp steep conical test which is circular in cross-section. The angle of the cone is generally 12 to 14° for normal uncompressed microspheric specimens and usually is a degree or two less for megalospheric forms. This second chamber has regular gentle transverse swells and constrictions giving it an annulate appearance. These indicate a tendency to form chambers, yet there is no thickening of the wall internally opposite the constrictions. In many specimens these are not conspicuous nor apparent. In a few, the mature last swelling flares out slightly forming a pronounced separation with the previous expansion. All specimens are broken off at the apertural end revealing the expanded funnel-shaped interior. Rarely a specimen is found which has the terminal portion preserved to show the constricted circular aperture (Pl. 149, fig. 15).

The test is made up of well-cemented fine silt-size quartz grains which give the surface a finely granular to smooth texture. The latter tend to be slightly glossy and irridescent.

Microspheric tests are commonly larger than megalospheric ones. Measurements in millimeters of figured specimens are as given at bottom of page.

Welden specimens appear to be slightly more robust than the Chappel specimens. The early part of the test may be translucent, but some of the white specimens have this portion either filled or replaced with pyrite or marcasite. The Chappel specimens have well cemented but slightly thinner

	Welden specimens				Chappel specimens	
	Pl. 149 fig. 15	Text-fig. 3—11	Pl. 3 fig. 10	Pl. 3 fig. 9	Text-fig. 4—12	Text-fig. 4—21
Length	0.80	1.05	0.88	0.65+	0.79	0.80
Maximum diameter	0.30	0.28	0.23	0.18+	0.18	0.20
Diameter proloculus		0.04	0.027	0.07	0.05	0.035?
Cone angle	19°	15½°	14°	13½°	10°	12°
Diameter aperture	0.21					

walls than the Welden specimens. They are usually white and uncompressed.

Remarks.—We are following Conkin (1954) and Crespin (1958) for the generic assignment. There are several species which *Hyperammina conica* resemble but the following distinctions are noted. The microspheric(?) test of *Hyperammina spinescens* Cushman & Waters is like the microspheric test of *Hyperammina conica* but there is no similarity with the megalospheric forms. The Welden and Chappel specimens resemble *Hyperammina johnsvalleyensis* Harlton, 1933, from the Pennsylvanian but this form has a compressed second chamber and reaches a much larger size than the Mississippian specimens. *Hyperammina nitida* Gutschick & Treckman, 1959, is similar, but it has a smaller conical angle. *Hyperammina conica* is not present in the Rockford limestone of northern Indiana, but it is common in a shale above the Rockford limestone (upper Rockford shale of Guy Campbell) in the southern part of the State. It is similar in shape to *Reophax buccina* Gutschick & Treckman, 1959, also from the Rockford, but *R. buccina* has a more distinctly chambered test, larger proloculus, and thicker wall made of coarser quartz grains than *Hyperammina conica*. The Pennsylvanian and Permian specimens of *Hyperammina elegans* (Cushman & Waters) have a shape similar to *Hyperammina conica*. They attain much greater size, however. A similar form occurs in abundance in the Sappington algal zone in southwestern Montana.

HYPERAMMINA CONSTRICTA Gutschick & Treckman

Pl. 149, figs. 6,7; Text-figs. 3—7,4—9–11

Hyperammina constricta GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 237, pl. 34, figs. 17–19; text-fig. 1—M,N.

This species occurs in the Chappel limestone of central Texas and the Welden limestone of Oklahoma. Little can be added to supplement our knowledge of this species. There is great uniformity among specimens from these widely separated localities. It is almost exclusively curvilinear and without proloculus due to apparent very small size and fragility of the initial chamber. Specimens with the last chamber and aperture are rare, but there are some in the Chappel which indicate that the apperture is circular and terminal. Of generic significance is the fact that the aperture is constricted to about half the diameter of the last chamber.

Hyperammina constricta is very common in the Chappel limestone from the White's Crossing section where over 50 well-preserved mature specimens were picked out of the samples for study, and many more are present. Specimens were also obtained from the Welden limestone at its type locality and in the Jackfork Creek section, but they are not as common or as well developed as in the Chappel limestone of Texas. This species was not found in our samples of the Lodgepole limestone of Montana.

This species is easily recognized. It has a glossy fine-textured well-cemented arenaceous test which is slightly translucent and irridescent. It is slender, is gently curved and is gradually tapering. It has regularly spaced constrictions throughout. Several small complete tests are placed in this species (Pl. 149, fig. 6; Text-fig. 4—10). They have all the characteristics of the typical specimen except the constrictions are only slightly developed or are not apparent. There is some indication that these represent the proloculus and early portion of the second chamber of mature individuals. If this is true, the entire test could be two or more millimeters in length.

The types are from the Rockford limestone of northern Indiana.

HYPERAMMINA GRACILENTA Gutschick & Treckman

Pl. 149, figs. 3,4; Text-fig. 3—5,6

Hyperammina gracilenta GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 237, pl. 34, figs. 10–11; text-fig. 1—G–I.

This species was first recognized in the Rockford limestone of northern Indiana where it is quite rare. However, material on hand from the Welden limestone of the type area yielded well-preserved specimens which are the types. The species is typically represented by megalospheric specimens which are characterized by a large spherical proloculus sharply separated from an evenly cylindrical second chamber. The aperture is formed by the open end of the tube. The test is composed of fine to medium quartz

grains which give it a granular surface texture. The Welden specimens are well cemented whereas the few Rockford specimens are not well cemented.

Microspheric(?) specimens are recognized in the Welden limestone. They are almost complete and consist of a small spherical proloculus and a slender cylindrical second chamber which expands only very slightly. The size of the quartz grains and surface texture is identical to the megalospheric specimens. The overall size of the microspheric(?) specimens is smaller than the megalospheric specimens. Fifteen megalospheric and five microspheric(?) specimens were selected for study.

The general form of the test resembles *Hyperammina elegans* Rauser-Cernoussova & Reitlinger, 1937, from the Lower Carboniferous, Tournaisian, of the Ural Mountains and Samara Bend area of Russia. They may be identical, but the Welden specimens do not have a smooth surface. The species *Hyperammina gracilenta* has not been recognized in either the Chappel or Lodgepole limestones.

The holotype is from the Welden limestone of Oklahoma and the paratypes are from the Rockford limestone of northern Indiana.

HYPERAMMINA KENTUCKYENSIS Conkin
Pl. 149, fig. 1; Text-fig. 5—3–5,22

Hyperammina kentuckyensis CONKIN, 1954, Contrib. Cushman Found. Foram. Res., v. 4, p. 165–169, pl. 31, figs. 1–6.

Hyperamminids are extremely common in the middle part of the Lodgepole limestone from locality 5, east by southeast of Doherty Mountain. More than 300 specimens were selected from this collection for study. Comparison was made with specimens furnished by James Conkin of the University of Louisville from the type area. The Lodgepole specimens were found to be closely similar.

The Lodgepole specimens without exception, consist only of the second chamber with the proloculus broken off. Both megalospheric and microspheric forms seem to be present, but the former type seems to be much more numerous. Microspheric forms, as in the types, have an inherently weak proloculus which is always broken. However, megalospheric specimens have a weak sutured constriction in the "hour class" portion of the test which accounts for the separation of the two chambers in acid residues. Many well-preserved megalospheric proloculi with short frayed tubular necks are found in the sample.

The typical Lodgepole form is slightly curved and expands gradually, resembling Conkin's megalospheric types. Mature specimens average about 1.5 mm. in length and 0.14 mm. in maximum diameter at the apertural end. This is larger than the type specimens. The aperture which is terminal is constricted and often has an enlarged rim or lip around it. The mature proloculus of megalospheric specimens has a diameter which varies from 0.13 to 0.15 mm. This probably is about the same size as the maximum diameter of the second chamber.

This species has not been found in the Welden, Chappel, Rockford limestones or in the foraminiferal zone in the basal portion of the Lodgepole limestone.

Types are from the Mississippian (Osagian) Floyds Knob formation of southwestern Jefferson County, Kentucky.

HYPERAMMINA ROCKFORDENSIS
Gutschick & Treckman
Pl. 149, figs. 2,5; Text-figs. 3—1–4; 4—17,18,25,26; 5—6(?)

Hyperammina rockfordensis GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 238, pl. 34, figs. 1–5; text-figs. 1—A–C.

There are fragments of an elongate cylindrical hyperamminid in the Welden, Chappel, and Lodgepole limestones which resemble the Rockford types. Remarks concerning specimens in the collection are summarized as follows:

Welden specimens: Foraminifera of this species are fairly common in the Welden, but the material is fragmental. However, a few complete specimens have been recovered. They closely resemble the Rockford material. The second chamber is elongate and expands very gradually, becoming cylindrical in its mature portion. One small entire specimen is 1.13 mm. in length, 0.07 mm. in maximum diameter, 0.04 mm. minimum diameter, and 0.06 mm. in diameter of

proloculus. The identification is based on a study of some 40 specimens.

Chappel specimens: Specimens in this collection are fragile and fragmental, consisting of the proloculus and a short segment of the second chamber or fragments of the second chamber without the proloculus. No entire specimens were recovered. From these fragments, it is clear that the form is slender, cylindrical and elongate with a spheroidal to ellipsoidal megalospheric proloculus, characteristic "hour glass" reduction in diameter of the early portion of the second chamber, and a slightly constricted aperture. A rim or lip around the aperture is present in some specimens. Very few specimens have been recovered from the residues. Megalospheric proloculus averages 0.09 mm. in diameter. Maximum diameter of the second chamber is about 0.10 mm.

Lodgepole specimens: Some ten or more relatively short cylindrical megalospheric specimens have been questionably placed in this species. They are almost identical with specimens of the Rockford horizon. A typical specimen has the following measurements: 1.2 mm. in length, 0.11 mm. in maximum diameter, 0.085 mm. minimum diameter, 0.125 mm. diameter of the proloculus. Since these specimens occur in association with abundant specimens of *Hyperammina kentuckyensis* Conkin, it is conceivable that they represent an elongate broken early portion of this species.

The types are from the Rockford limestone (Kinderhookian) of northern Indiana.

Family REOPHACIDAE Cushman
Genus REOPHAX Montfort
REOPHAX CALATHUS, n. sp.
Pl. 149, figs. 18,26; Text-fig. 5—14

The test is free, elongate, straight to slightly arcuate and consists of five to six or more ovoid chambers. The crude spherical proloculus is not too well defined. It is usually axial but in a few specimens it is off-center. However, it is common to find the proloculus broken off completely. The proloculus and first chamber or two which are usually small are made up of solid translucent granular silica in contrast to the etched porous nature of the remainder of the test. The test wall is apparently made up of calcareous spicular material cemented together by granular silica. Hydrochloric acid treatment eliminates the slender calcareous rods and produces a very cellular porous test characterized by having a preferred lineation of the spicules more or less parallel to the length of the test. The spicules generally are uniform in size and shape for each chamber and increase in size for succeeding chambers. The first two or three chambers are narrow, small, and elongate with little or no constriction between them. There is gradual expansion of the next few chambers with more noticeable segmentation, although this is difficult to detect in some specimens. The last chamber is larger and slightly expanded with a prolate ellipsoidal shape which may have a very slight indication of spiral twist. Internally the chambers appear to be simple and nonlabyrinthic with no separation between them other than the constrictions of the wall. The test has its greatest diameter at the proximal end of the last chamber from which it tapers gently towards the aperture where it becomes pinched abruptly at the terminal end. The nature of the aperture is not clear although it appears to be a constricted single small opening in the central and terminal area.

Over 50 specimens were found and selected for study. Less than 20 are fairly complete. Specimens come from above the middle of the Lodgepole limestone at locality 5. They occur sparingly in the basal Lodgepole at locality 4. Measurements in millimeters of the holotype and three other well-preserved mature specimens from locality 5 are given below:

	Holotype	Paratype	Paratype	Paratype
Length	2.25	2.46	2.12	2.10
Maximum diameter	0.40	0.47	0.38	0.40
Number of chambers	6	6	6	6
Length of last chamber	0.70	0.80	0.75	0.65
Diameter of proloculus	0.08	—	0.09	0.09

The wall thickness of a typical mature specimen is about 0.06 mm.

Remarks.—This is a very unique species, especially since it is extracted from acid residues. It is a rectilinear to curvilinear uniserial test composed of sorted, parallel-oriented calcareous spicules. Unfortunately, specimens extracted from acid residues do not give direct information on the nature of the spicules. However, it would otherwise be difficult to find a specimen intact in the limestone by other means. In picking over sample trays of the residue for Foraminifera specimens, this form was ignored because it superficially looked much like a wheat or grass seed which commonly finds its way into samples. Additional specimens and the hardness test prompted more consideration, revealing its identity. The specific name was chosen because of the resemblance of specimens to elongate vase-shaped or lily-shaped baskets.

The recent species *Reophax spiculifera* Brady has siliceous spicules arranged side by side more or less parallel to the length of the test. Except for this pattern which matches the Lodgepole form, the above species has little semblance.

REOPHAX LACHRYMOSA Gutschick & Treckman
Pl. 149—figs. 11,17; Text-fig. 5—19,20

Reophax lachrymosa GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 240, pl. 34, figs. 20–25, text-fig. 2—A,B.

About 15 specimens of a uniserial form from the Lodgepole limestone are questionably assigned to this species. Most specimens have been flattened and deformed by compaction, which makes them difficult to compare with the Rockford type material. However, two incomplete specimens are uncompressed and afford statistical comparison. Measurements on these in millimeters are as follows:

	Pl. 149 fig. 11	Pl. 149 fig. 17
Length (incomplete)	1.39	1.00
Maximum diameter of largest chamber	0.16	0.12+
Diameter of proloculus	0.08	0.095
Number of chambers present	6 or 7	5

The wall thickness measured around the proloculus for another specimen is approximately 0.020 mm.

The Lodgepole specimens do not seem to have chambers as pyriform-shaped as the Rockford types. Otherwise, they agree quite closely. The proloculus and extension leading to the first constriction is identical to specimens of *Reophax lachrymosa* from the Rockford. The photographs and drawings of the better specimens do not show clearly the constrictions and pyriform chambers because of distortion of the individuals. All specimens assigned to this species in this paper are from the Lodgepole limestone collected at locality 5.

The types are from the Rockford limestone of northern Indiana.

REOPHAX sp.
Text-fig. 5—12

A single small specimen was found in the Lodgepole limestone of Montana which is quite different from any other species. It merits description until more material can be found on which to base a specific identification. It is uniserial with slight curvature of the test in the early portion which becomes straight in the mature portion. The size of the chambers gradually increases but the test is relatively narrow compared to its length. Chambers are globular to prolate ellipsoidal. The test is composed of coarse silt grains with a relatively small amount of silica cement so that the surface is rough and granular. The proloculus is missing and the last chamber is broken. However, six complete chambers can be recognized.

Measurements of the specimen in millimeters are as follows:

Length	0.73
Maximum diameter	0.18
Length of largest chamber	0.14

Reophax minutissimus Plummer, 1945, of the Pennsylvanian of Texas is the closest to this specimen. However, the Pennsylvanian species has a glossy surface.

Family TOLYPAMMINIDAE Cushman
Genus TREPEILOPSIS Cushman & Waters
TREPEILOPSIS GLOMOSPIROIDES Gutschick & Treckman
Pl. 149, fig. 25; Text-fig. 5—13, 21

Trepeilopsis glomospiroides GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 243, pl. 35, figs. 29–31.

The tolypamminid genus *Trepeilopsis* re-

presenting a spirally coiled foraminifer about some object of attachment, usually a productid spine, is present in the basal beds of the Lodgepole limestone at locality 4. Only a few complete individuals have been found, but much fragmentary material is present in the samples. Although the Montana form is not exactly like the Rockford types, it was placed in this species rather than to establish a new species on insufficient specimens. It resembles the Rockford specimens in that it coils progressively about a slender rod or spine and terminates in a glomospiroid "knob."

The test of this Lodgepole form consists of four parts. The earliest portion is disorganized and has irregular coiling even to the extent of becoming glomospiroid. This is followed by regular spiral coiling which is tight and becomes progressively larger with the growth of the individual. The third portion is straight or very slightly twisted along the linear object of attachment. This part is essentially uncoiled. The fourth part is the tight glomospiroid coiling to the apertural terminus which is the open end of the expanded tube.

Measurements of a well-preserved complete specimen in millimeters are as follows:

	Pl. 149 fig. 25
Total length of test	1.77
Greatest diameter	0.30
Length of first part	0.68
Length of spirally coiled portion	0.63
Length of uncoiled portion	0.14
Length of glomospiroid part	0.35
Greatest diameter of the tube	0.15

The wall consists of fine silt-size grains and is not thick or strong.

The occurrence of complete specimens of these fragile fossils emphasizes the importance of dealing with whole specimens for working out the taxonomy of the tolypammminids. It also indicates the latitude of growth expression which these forms have.

The types are from the Rockford limestone of northern Indiana.

Genus TOLYPAMMINA Rhumbler
TOLYPAMMINA CYCLOPS Gutschick & Treckman
Pl. 150, figs. 5,7,9,10; Text-fig. 3—15,16

Tolypammina cyclops GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 245, pl. 36, figs. 1–2,4,6–7,10–14.

This species is present in both Chappel and Welden limestones where it is fairly common and also in the Lodgepole limestone where individuals are underdeveloped and uncommon.

The types are from the Rockford limestone of northern Indiana.

TOLYPAMMINA EXTENDA (?) Ireland
Pl. 150, fig. 13

Tolypammina extenda IRELAND, 1956, Jour. Paleontology, v. 30, p. 849, text-figs. 4—23,24.

A single specimen was found in the Chappel limestone of locality 3; otherwise the species has not been recognized in the other formations.

The type is from the Upper Pennsylvanian of Kansas.

TOLYPAMMINA ROTULA Gutschick & Treckman
Pl. 150 figs. 1,2; Text-fig. 4—1

Tolypammina rotula GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 246, pl. 36, figs. 5,8–9; pl. 37, figs. 1–3.

This species is common in the Chappel and the Welden limestones in localities 1,2, and 3, but was not recognized in the Lodgepole limestone. Specimens tend to be fragmentary, but they are present in sufficient quantity to make close comparison with the types.

The types are from the Rockford limestone of northern Indiana.

TOLYPAMMINA SPERMA, n. sp.
Pl. 150, fig. 12

This form is usually attached in part and consists of a globular pointed proloculus and a gradually expanding second chamber. The proloculus is top-shaped if free and heart-shaped if attached. In both cases, the pointed portion is directed away from the second chamber. The pointed portion of the proloculus is usually fairly sharp, but it may be extended and terminate with a rounded tip. The surface of attachment develops a flattened side which gives the opposite free portion a heart-shape appearance. There usually is a constriction between the proloculus and second chamber, from which the latter gradually expands. The second cham-

ber may be circular or oval in cross section. If it is attached, it has a flattened surface on the side of attachment. The aperture apparently is the open end of the second chamber. Both microspheric and megalospheric forms are recognized. Megalospheric forms are more common and have a large proloculus of the same shape as the microspheric specimens and a smaller second chamber, resulting in a test which is smaller than the microspheric form.

This species is identified in the Welden and Chappel limestones and the Rockford limestone and upper Rockford shale of Indiana. The holotype (Pl. 150, fig. 12) is a fairly complete microspheric specimen from the Welden limestone. The individuals in this formation have a robust, well-cemented, thick-walled test. This is also true of the specimens in the upper Rockford shale. However, Chappel specimens have a thinner wall which is not as strong as those from the other formations. None has been recognized in the Lodgepole limestone.

The wall of the test is made up of coarse silt-size quartz grains moderately cemented together with silica. The surface has a granular texture. Measurements of typical specimens in millimeters are given below:

	Welden Pl. 150, fig. 12 Holotype	Chappel	Chappel
Type of proloculus	microspheric	megalospheric	megalospheric
Width of proloculus	0.085	0.14	0.15
Length of proloculus	0.095	0.19	0.35
Length of test	2.85+	1.02+	
Maximum diameter	0.60	0.13	
Proloculus	unflattened	flattened	flattened

Remarks.—The unique shape of the proloculus distinguishes this species from other described tolypamminids. The species is named for the resemblance of megalospheric forms of the test to a spermatozoon.

Genus AMMOVERTELLA Cushman
AMMOVERTELLA BULBOSA
Gutschick & Treckman
Pl. 150, fig. 4

Ammovertella bulbosa GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 247, pl. 37, figs. 4,5,8,9.

A few specimens of this species occurs in the Chappel and Welden limestones.

The types are from the Rockford limestone of northern Indiana.

Family LITUOLIDAE Reuss
Genus AMMOBACULITES Cushman
AMMOBACULITES CHAPPELENSIS, n. sp.
Pl. 149, figs. 19,20–22;
Text-figs. 3—25, 4—27

Ammobaculites? sp. GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology v. 33, p. 249, pl. 37, figs. 18,20,26,27.

This common species consists of a lace-like fragile test which has a small proloculus followed by chambers coiled in a plane for three or four whorls which then uncoil into a uniserial portion. It is important to understand that the tests are porous, lace-like, skeletal, delicate and fragile. They are composed of agglutinate arenaceous grains. Their fragility is due either to a very thin poorly cemented wall structure or the presence of calcareous grains which dissolve in acid treatment leaving a skeletal test. We consider that the latter is correct. Quartz, lime sand, and silt grains were used in the test cemented together by fine silica. The lime grains reach a maximum size of very fine sand. Holes in the tests recovered from acid residues appear to be places where the lime grains were dissolved.

The small thin fragile proloculus is broken in most specimens, and it is difficult to see in more nearly complete specimens using low magnification. It was observed with the use of transmitted light and higher magnification in a number of more nearly complete specimens mounted in Lakeside Cement. The coiled part of the test consists of the small spheroidal proloculus and successive gradually expanding chambers planispirally coiled into three or four evolute whorls. The inner whorls are crowded and difficult to see in whole specimens, except with the use of

transmitted light. Their chambers are ill-defined and obscure. The outer whorl has six to seven fairly well defined elongate chambers, each of which becomes inflated at right angles to the plane of coiling. Succeeding chambers are uniserially arranged. It is not known how many uniserial chambers make up a complete test, as most specimens have this portion broken off from the planispiral part. The most nearly complete specimen found in the residues has two complete chambers and portions of a third still attached to the coiled part. The chambers are prolate ellipsoidal in shape. This portion of the test in Welden specimens is well cemented so as to appear tubular. No information is available concerning the aperture of this species.

The following measurements in millimeters were made of specimens from each of the three limestone formations

	Chappel Pl. 149, fig. 22 Holotype	Chappel	Rockford	Welden
Length of the test (incomplete)	0.70+	0.77+	0.39	
Diameter of coiled portion	0.38	0.44	0.25	0.25
Maximum diameter of chambers	0.12	0.15	0.08	0.08
Maximum length of chambers	0.13			

Measurements were made on several Chappel specimens for diameter of proloculus and wall thickness. The former varies from 0.027 to 0. 045 mm., and the latter is about 0.010 to 0.015 mm. Specimens in the Chappel limestone of locality 3 are extremely abundant, moderately well preserved, and relatively large. The species occurs in localities 1 and 2 of the Welden limestone but is neither as common nor as large as the Chappel specimens. The preservation is very poor. This would also be true for the specimens in the Rockford limestone of northern Indiana.

Remarks.—The species is present in the Rockford, Welden and Chappel limestones but has not been found in the lower Lodgepole samples. It was first found and described from the Rockford limestone of Indiana but the specimens were so fragile and incomplete that it did not seem prudent to name them. Now that the form has been recognized in three widely separated areas and is so abundant in the Chappel as to be present literally by thousands of specimens, it seems justifiable to identify them specifically in spite of their incompleteness.

The form was placed in this genus because it has a planispiral and uniserial combination test which is composed of agglutinate arenaceous grains. It was placed in a new species because it is considered to have used both quartz and calcite grains joined together with a siliceous cement for its test. Ireland (1956) discusses isomorphism in connection with silica-grained *Ammobaculites* and lime-grained *Eneothyranella* analogs. *Ammobaculites chappelensis*, n. sp., is between the two genera above if both lime and silica grains were used to form its test. All specimens were obtained from hydrochloric acid residues. Under the circumstances the species is characterized by having specimens which are porous. They closely resemble *Ammobaculites pyriformis* Gutschick & Treckman, 1959, with which they are associated. However, the latter is composed entirely of quartz grains firmly cemented together with silica. *Ammobaculites chappelensis*, n. sp., lacks the pyriform shape of the chambers.

AMMOBACULITES LEPTOS
Gutschick & Treckman
Pl. 149, figs. 12,14;
Text-figs. 3—26, 5—15,16

Ammobaculites leptos GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 247, pl. 37, figs. 12,13.

This delicate form of *Ammobaculites* is present in the Welden, Chappel, and Lodgepole limestones in addition to the Rockford limestone of Indiana. More than 30 specimens have been recovered from both localities of the Welden limestone of Oklahoma. They have the typical small planispiral portion with obscure inner whorls and four or five chambers in the outer whorl of the test. The rectilinear part consists of three, four,

or more pyriform chambers. The species is not common in the Chappel limestone of locality 3 where only three or four well-preserved specimens were found. Three poorly preserved specimens were found in the Lodgepole limestone of locality 4 and these are partly compressed. There is little doubt that they belong to this species.

The types are from the Rockford limestone of northern Indiana.

AMMOBACULITES PYRIFORMIS
Gutschick & Treckman
Pl. 149, figs. 13,23,24;
Text-figs. 3—27,28; 4—24

Ammobaculites pyriformis GUTSCHICK & TRECKMAN, 1959, Jour. Paleontology, v. 33, p. 248, pl. 37, figs. 14–17,19,21–25; text-fig. 3—A,B.

This species is common in the Welden limestone where more than 50 well-preserved well-cemented specimens were recovered from the acid residues of limestone from localities 1 and 2. The specimens are robust representatives of this species. Most specimens have two or three chambers remaining in the uncoiled part of the test. Two well-preserved individuals were found in the Chappel limestone from locality 3, but they also have only parts of the first three chambers of the linear portion of the test and are smaller than the Welden forms. The genus *Ammobaculites* is present in the Lodgepole limestone but this particular species has not been recognized in our samples.

The types are from the Rockford limestone of northern Indiana.

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JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1222–1243, 8 TEXT-FIGS., NOVEMBER, 1961

PALEONTOLOGICAL NOTES

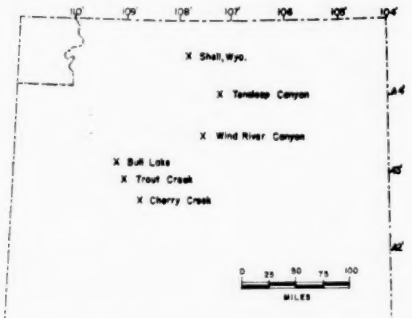
CHAETETES IN THE TYPE SECTION OF THE TENSLEEP FORMATION, TENSLEEP CANYON, WASHAKIE COUNTY, WYOMING

JACK D. BURGESS
Humble Oil & Refining Company, Billings, Montana

Recent interest in both the geographic and stratigraphic occurrence of the tabulate coral *Chaetetes* (Dott, 1954, 1955; Rich, 1960) prompts this note on its occurrence in the type section of the Tensleep formation and elsewhere in central Wyoming. It is hoped that future work may prove its stratigraphic value in the generally unfossiliferous rocks of the Pennsylvanian system of the northern Rocky Mountains.

The Tensleep formation was named by Darton (1906) from exposures in the Big Horn Mountains at Tensleep Canyon, Washakie County, Wyoming (Text-fig. 1). He correlated both the Pennsylvanian Tensleep and the underlying Amsden formation with the Minnelusa of the Black Hills, the Hartville formation of the Hartville region, and the lower Pennsylvanian (Lyons, Ingleside, and Fountain) in eastern Colorado.

Fossils are rarely found in either the Tensleep or Amsden formations in central Wyoming, but the identified forms indicate a Desmoinesian age for the Tensleep (Brainerd & Keyte, 1927; Branson, 1939; Hoare and Burgess, 1960), and a slightly older Pennsylvanian stage for the Amsden (Burk, 1954).



TEXT-FIG. 1—Index map of Wyoming showing location of fossil collections.

Chaetetes has not previously been reported from the Tensleep in the Big Horn Basin of Wyoming. It was first identified in the formation by Branson (1939) from exposures along Bull Lake Creek in the Wind River Mountains to the west. Here, *Chaetetes* was found 293 feet below the top of the formation.

The coral sample was collected in the SW¼ sec. 1, T. 47 N., R. 88 W., from the north wall of Tensleep Canyon near the fish-hatchery bridge by Jim McCreight of Humble Oil & Refining Company, Worland, Wyoming. It was found 127 feet below the top of the formation and 36 feet above a basal pebble conglomerate marking the contact with the underlying Amsden formation. The coral head measured six inches in diameter and occurred in a 4-foot red sandy limestone unit. It has been dolomitized, but the tubulae and other details are well preserved and readily apparent in polished section.

Because no fusulinids were found in the type section of the Tensleep formation, the exact stratigraphic position of *Chaetetes* in relation to established Pennsylvanian fusulinid zones is unknown here.

The nearest fusulinid control, as a means of stratigraphically locating *Chaetetes* in the type Tensleep section, is about 35 miles to the northwest near Shell, Wyoming. A fauna from this locality was identified by M. L. Thompson (personal communication) and contains *Fusulina* sp. and *Fusullinella?* sp. This fauna was collected by the writer from chert nodules in the upper ten feet of the Tensleep.

At Wind River Canyon in the Owl Creek Mountains, 40 miles to the southwest, a fusulinid fauna identified by Branson (1939) was collected 175 feet below the top of the Tensleep formation. It included *Fusulina*, n. sp., and *Staffella* sp.

The writer collected *Chaetetes* and fusu-

linids from exposures along both Trout and Cherry Creeks in the Wind River Mountains (Text-fig. 1). The fusulines occur anywhere from 50 to 150 feet above the *Chaetetes* heads, but none is found below them. The fusulinids were identified by M. L. Thompson (personal communication), and include *Wedekindellina* cf. *W. euthysepta* Henbest and *Fusulina pumila* Thompson.

Chaetetes, where presently found in the type section of the Tensleep formation, probably is of lower Desmoinesian age, on the basis of identified fusulinids associated with it elsewhere in central Wyoming. If this age assignment is correct, *Chaetetes* is younger in central Wyoming than farther west where it is found associated with Atokan fusulinids (Dott, 1954, 1955; Rich, 1960). However, the Desmoinesian age assignment of *Chaetetes* in central Wyoming is more nearly of the same age as *Chaetetes* in the midcontinent region where Dunbar & Condra (1932) consider it an index fossil for Desmoinesian rocks.

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THREE NEW CONODONTS FROM THE LOUISIANA LIMESTONE (UPPER DEVONIAN) OF WESTERN ILLINOIS

ALAN J. SCOTT

The University of Texas, Austin, and Illinois State Geological Survey, Urbana

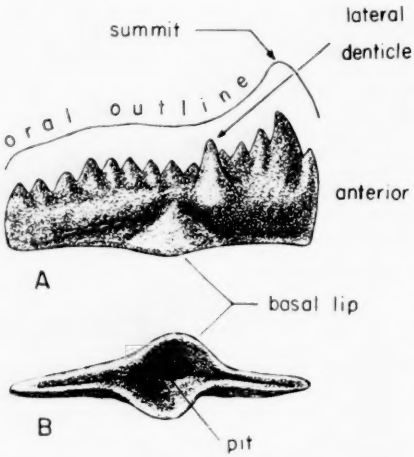
The age and stratigraphic relationships of the Louisiana Limestone in the Upper Mississippi Valley have long been a source of controversy. Scott & Collinson (1961) recently described and compared the conodont fauna of the Louisiana Limestone with previously described Devonian and Lower Carboniferous conodont faunas from western Europe. On the basis of the conodont evidence the Louisiana is latest Devonian in age and is correlated with the *Wocklumeria* Stufe (toVI) of the Rhenish Schiefergebirge.

Although a total of 38 species, referable to 17 genera, was reported from the Louisiana Limestone, only a few species are common:

Polygnathus communis Branson & Mehl.
Gnathodus cf. *G. commutatus* (Branson & Mehl)
G. kockeli Bischoff
Spathognathodus inornata (Branson & Mehl)
Palmatolepis spp.

Three additional species *Spathognathodus* n. sp., *S. collinsoni*, n. sp., and *S. culmineirectus*, n. sp., are important in this fauna. Spathognathodids are common and stratigraphically useful forms in units near the Devonian-Mississippian boundary.

Morphologic terminology used in the description of these species is shown in Text-figure 1. The specimen figured in Text-figure 2C was collected from the Louisiana Limestone at Poor Farm Hollow, SW¼ NW¼ sec.



TEXT-FIG. 1—Morpholigic terms used in the description of spathognathodids. *A*, inner lateral view of *Spathognathodus* sp.; *B*, aboral view of *S.* sp. Both figures approximately ×35.

22, T. 10 S., R. 2 W., Calhoun County, Illinois. All other specimens in Text-figure 2 were collected from the Louisiana at Teneriffe School, SE¼ NE¼ sec. 8 and SW¼ NW¼ sec. 9, T. 7 N., R. 13 W., Jersey County, Illinois. Measured sections and descriptions of these and other Louisiana collecting localities are given in Scott & Collinson (1961).

SYSTEMATIC PALEONTOLOGY

Genus SPATHOGNATHODUS Branson & Mehl

Type species.—*Spathodus primus* Branson & Mehl

Spathodus BRANSON & MEHL, 1933, Univ. Missouri Studies, v. 8, no. 1, p. 46 [*not* BOULENGER, 1900].
Spathognathodus BRANSON & MEHL, 1941, Jour. Paleontology, v. 15, p. 98.
Mehlina YOUNGQUIST, 1945, ibid., v. 19, p. 363.
Branmehla HASS, 1959, U. S. Geol. Survey, Prof. Paper 294J, p. 381.
Ctenognathodus FAY, 1959, Jour. Paleontology, v. 33, p. 195.

Remarks.—Müller & Müller (1957, p. 1082) considered *Spathognathodus* a junior synonym of *Ctenognathus* Pander, 1856. According to Hass (1959, p. 379) the latter name is preoccupied by *Ctenognathus* Fairmaire, 1843. Müller & Müller also considered *Prioniognathus* Pander, 1856, as being a synonym of *Ctenognathus* and therefore as having priority over *Spathognathodus*. The holotype of *Prioniognathus branetii*, the type species of that genus, is broken and it is impossible to determine whether *P. branetii* has characteristics attributed to *Spathognathodus* by subsequent workers. It therefore seems advisable to retain the name *Spathognathodus* for the sake of stability in taxonomic nomenclature.

The reasons for placing *Branmehla* Hass in synonymy with *Spathognathodus* are briefly discussed by Scott & Collinson (1961, p. 132).

SPATHOGNATHODUS ANTEPOSICORNIS Scott, n. sp.

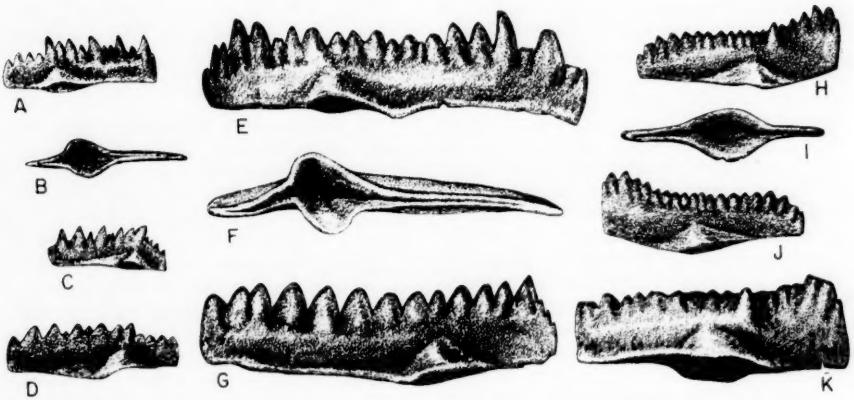
Text-fig. 2H-K

Spathognathodus n. sp. A. SCOTT & COLLINSON, 1961, Kansas Geol. Soc. 26th Ann. Field Conf. Guidebook, p. 132, pl. 1, figs. 12–15.

This is a representative of *Spathognathodus* characterized by the presence of a single well developed lateral denticle on the inner side of the unit immediately anterior to the basal pit.

The unit is elongate, about three times as long as high, nearly straight or only slightly bowed laterally, with the basal pit located in the middle one-third. The oral outline is lowest at the posterior end, nearly straight across the middle third of the unit, and rises to its highest point near the anterior end of the unit. The aboral edge is nearly straight or curved upward slightly at the anterior end. The denticles on the oral edge are partly fused but have short discrete rounded tips. Two to four denticles at the extreme anterior end are slightly larger. A prominent horn-like lateral denticle is developed on the inner side of the unit near the anterior edge of the widely flared basal lip that flanks the basal pit.

Remarks.—This species is one of the most characteristic forms in the conodont fauna of the Louisiana Limestone. Several spathognathodids with lateral denticles previously have been described. Most of these forms, e.g., *Spathognothodus aculeatus* (Branson & Mehl) and *S. tridentatus* (E. B. Branson), have more than one lateral denticle. Faunas from both the underlying Saverton Shale and the overlying Hannibal Formation con-



TEXT-FIG. 2A–D—*Spathognathodus collinsoni* Scott, n. sp. *A*, lateral view of holotype (4P3055); *B*, aboral view of holotype; *C*, lateral view of immature specimen (4P3085); *D*, lateral view of large specimen (4P3007) with fused denticles.

E–G—Spathognathodus culminidirectus Scott, n. sp. *E*, lateral view of specimen (4P3003) with large denticles at both ends of the unit; *F*, aboral view of specimen (4P3002); *G*, lateral view of holotype (4P3000).

H–K—Spathognathodus anteposicornis Scott, n. sp. *H*, inner lateral view of holotype (4P3010); *I*, aboral view of holotype, *J*, outer lateral view of holotype; *K*, inner lateral view of large specimen (4P3045) with fused denticles.

All figures ×35.

tain spathognathodids with only a single lateral denticle; however, these forms have this denticle located posterior to or immediately over the basal pit.

During the ontogeny of this species the denticles tend to become fused, and the lateral denticle becomes more prominent in large specimens (Text-fig. 2K).

Occurrence.—A total of seven specimens was collected from the Louisiana. Hass (1947) has mentioned a spathognathodid from the basal part of the Bedford Shale of Ohio that has a description similar to the diagnosis of *Spathognathoeus anteposicornis*.

Derivatio nominis.—Compounded from Latin *anteposítus*, situated in front, and *-cornis*, having a horn.

Type specimens.—The specimen (4P3010) figured in Text-figures 2H, I, and J is here designated as the holotype of this species. A photograph of this specimen was published by Scott & Collinson (1961, pl. 1, fig. 13).

The figured paratype (4P3045) on Text-figure 2K corresponds to fig. 14 on pl. 1 *in* Scott & Collinson (1961). Other specimens used in defining this species are: (4P3068) = pl. 1, fig. 12, *in* Scott & Collinson (1961); (4P3053) = pl. 1, fig. 15, *in* Scott & Collinson (1961).

Unfigured specimens referred to *Spathognathodus anteposicornis* are stored in the collections of the Illinois State Geological Survey under the following numbers: (4P3061), (4P3072), and (4P3098).

SPATHOGNATHODUS COLLINSONI
Scott, n. sp.
Text-fig. 2A-D

Spathognathodus n. sp. B. SCOTT & COLLINSON, 1961, Kansas Geol. Soc. 26th Ann. Field Conf. Guidebook, p. 133, pl. 1, figs. 16–19,33.

Anterior to the basal pit are four to eight large, compressed denticles, subtriangular in outline, with a few smaller closely crowded denticles between some of the larger ones. The oral outline is lower posterior to the pit and bears three to five small subequal denticles.

The unit is elongate, only slightly bowed, about three times as long as high, with the pit located in the posterior one-third. The tips of the larger set of denticles form a nearly straight oral outline for the anterior

two-thirds of the unit; posterior to the pit this outline is much lower. The aboral edge of the unit is nearly straight and is not arched. The denticles are compressed, have discrete tips, and are subtriangular in outline. Four to eight large subequal denticles are located anterior to the pit. Smaller denticles are located anterior to the pit. Smaller denticles, closely crowded, are developed between some of these larger denticles near the center of the unit. Three to five small subequal denticles are developed posterior to the deep, almost bilaterally symmetrical pit, which is flanked by flared basal lips. The basal lips are widest near the pit and taper gradually toward the anterior end of the unit.

Remarks.—The denticles on some large specimens (Text-fig. 2D) tend to become fused and the small denticles on the anterior limb are gradually lost. The oral outline, which is straight over the anterior two-thirds of the unit and low over the posterior one-third, serves to distinguish even these large specimens from other spathognathodids such as *Spathognathodus inornata* (Branson & Mehl).

Occurrence.—This species is common in the conodont fauna of the Louisiana Limestone. It has not, as yet, been reported from other Devonian-Mississippian formations. A total of 12 specimens was obtained from the Louisiana.

Derivatio nominis.—This species is in honor of Charles Collinson, Geologist, Illinois State Geological Survey.

Type specimens.—The specimen (4P3055) figured on Text-figures 2A and 2B is here designated the holotype of this species. Photographs of this specimen were published by Scott & Collinson.

Figured paratypes (4P3085), Text-figure 2C, and (4P3007), Text-figure 2D, were illustrated by Scott & Collinson.

Unfigured paratypes are stored in the collections of the Illinois State Geological Survey under the following numbers: (4P3059), (4P3074), (4P3096) and (4P3097).

SPATHOGNATHODUS CULMINIDIRECTUS
Scott, n. sp.
Text-fig. 2E-G

Spathognathodus n. sp. C. SCOTT & COLLINSON, 1961, Kansas Geol. Soc. 26th Ann. Field Conf. Guidebook, p. 133, pl. 1, figs. 29–31.

This is representative of *Spathognathodus* characterized by an oral outline that is nearly straight or slightly higher at both ends of the unit.

The unit is thick, elongate, about four times as long as high, with the pit located in the posterior one-half. The oral edge bears 14 to 24 closely crowded partially fused denticles that have subrounded or pointed discrete tips. Commonly the denticles located near the ends of the unit are slightly larger and may be higher than the other denticles; otherwise the oral outline is nearly straight. Most specimens have two to four minute denticles developed at the extreme posterior edge of the unit. The denticle located over the pit may be slightly larger than surrounding denticles, but it is never prominent. The aboral edge is slightly lower near the pit and is not arched.

The unit is flexed inward slightly just posterior to the prominent sybsymmetrical pit, which is deep and surrounded by flared basal lips.

Remarks.—This species is much larger than other spathognathodids from the Louisiana Limestone. The oral outline serves to distinguish immature specimens of *Spathognathodus culminidirectus* from mature specimens of *S. collinsoni* n. sp., and *S. inornata* (Branson & Mehl). This last has the highest point on the oral edge over the pit.

Occurrence.—This species is relatively common in the Louisiana Limestone and also occurs in the youngest beds of the Saverton Shale in western Illinois. A total of 12 specimens was collected from the Louisiana Limestone.

Derivatio nominis.—Compounded from Latin *culmen*, the top, and *directus*, straight.

Type specimens.—The specimen (4P3000) figured in Text-figure 2G is here designated as the holotype of this species. This specimen was also illustrated by Scott & Collinson (1961, pl. 1, fig. 31).

Paratypes figured in this paper are:

(4P3003) = Text-figure 2E = pl. 1, fig. 29, *in* Scott & Collinson (1961).
(4P3002) = Text-figure 2F = pl. 1, fig. 30, *in* Scott & Collinson (1961).

Other specimens used in describing this

species are stored in the collections of the Illinois State Geological Survey under the numbers (4P3084), (4P3089), (4P3099), and (4P3100).

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NEW PLANT SPORES SIMILAR TO *TORISPORA* BALME

FRANK L. STAPLIN
Imperial Oil Limited, Calgary, Canada

ABSTRACT—Two species with pronounced gibbosities from Tournaisian and Famennian beds of Western Canada, *Torispora? tiara*, n. sp., and *Cornispora varicornata*, gen. et sp. n., are described. Triletoid as well as monolete phases are present. Associated with *C. varicornata* are subcircular spores with an asymmetrical thickening of the spore wall.

DISCUSSION

Horst (1957), Neavel & Guennel (1960), and Doubinger & Horst (in preparation) have contributed to an understanding of *Bicoloria* and *Torispora*. The latter paper describes all of the species of the true *Torispora*. The two species described in this note have some of the features of *Torispora*, but they differ in other details and have not been found in *Bicoloria*-like groupings.

A number of spores with large distal structures are known from Carboniferous strata. *Tholisporites* Butterworth & Williams, 1958, from the Limestone Coal group of Scotland consists of a spore body tightly enclosed distally and equatorially by a very thick structure to which the name patina was applied. (The term patella is preferable, as patina has acquired several meanings in geological usage, the most frequent being that of a thin overall coating.) Unlike *Murospora*, compression seemingly is not frequent in the equatorial plane. The type species of *Murospora*, *M. kosankei* Somers, 1952, also consists of two layers; the inner relatively thin wall of the spore body is tightly enclosed on all sides by a thick outer layer, or capsula (Staplin, 1960; Pocock). Patellate species also were assigned to the genus by Staplin because of the generally similar appearance of capsulate and patellate forms. *Murospora* and *Tholisporites* have trilete haptotypic structures, while most specimens of *Torispora* are monolete (including the *Crassosporites* and *Speciososporites* phases), although a number of specimens are tiletoid (asymmetrically triletoid) as noted by Alpern (1959).

Most single specimens of *Torispora? tiara*, n. sp., seem to be monolete, although this is difficult to establish because compression normally took place in the plane of the proximal-distal axis, obscuring the laesurae. The individuals in a single cluster of specimens that has the appearance of a tetrad in the process of separation are the only trilete forms that have been found, with the exception of two slightly different individuals from another locality and possibly different stratigraphic position. It is possible that the cluster does not represent a tetrad, but is a small portion of the wall of a *Bicoloria*-like organ. Tenuous support for the latter interpretation is contributed by specimens with a much reduced distal structure (Text-fig. 1—1) that approach the *Crassosporites* phase of the true *Torispora*. Specimens of this kind are infrequent and may represent only

poorly developed individuals. *Torispora? tiara* occurs in sediments generally correlated with the Banff formation, in part Tournaisian in age, and considerably older than those containing the true *Torispora* (Westphalian, Stephanian).

Cornispora varicornata, n. sp., has one to four subequatorial "horns." Because of the placement of these appendages, compression usually does not obscure the laesurae.

Most specimens are monolete, but a number are trilete; two of the rays are short and form an acute angle with each other. This triletoid arrangement is present in some specimens of *Torispora*, including the species in the Indiana paper coal (Neavel & Guennel) and in the Westphalian D sediments of Europe (Alpern, 1959). In the same samples with *Cornispora varicornata* occur subcircular spores with an asymmetrical thickening of the exine (Text-fig. 1—5), but these are relatively infrequent.

Since sporangial masses have not been found, it is impossible to relate either of the two species to the true *Torispora*.

Luber (1955) found spores similar to *Torispora? tiara*, with laevigate exinal protuberances, in the lowermost Carboniferous and Upper Devonian of the U.S.S.R.

Type specimens are in the type collections of Imperial Oil Limited, 300 Ninth Avenue S.W., Calgary, Alberta, Canada.

DESCRIPTIONS

Genus TORISPORA Balme
TORISPORA? TIARA Staplin n. sp.
Text-fig. 1—1–4

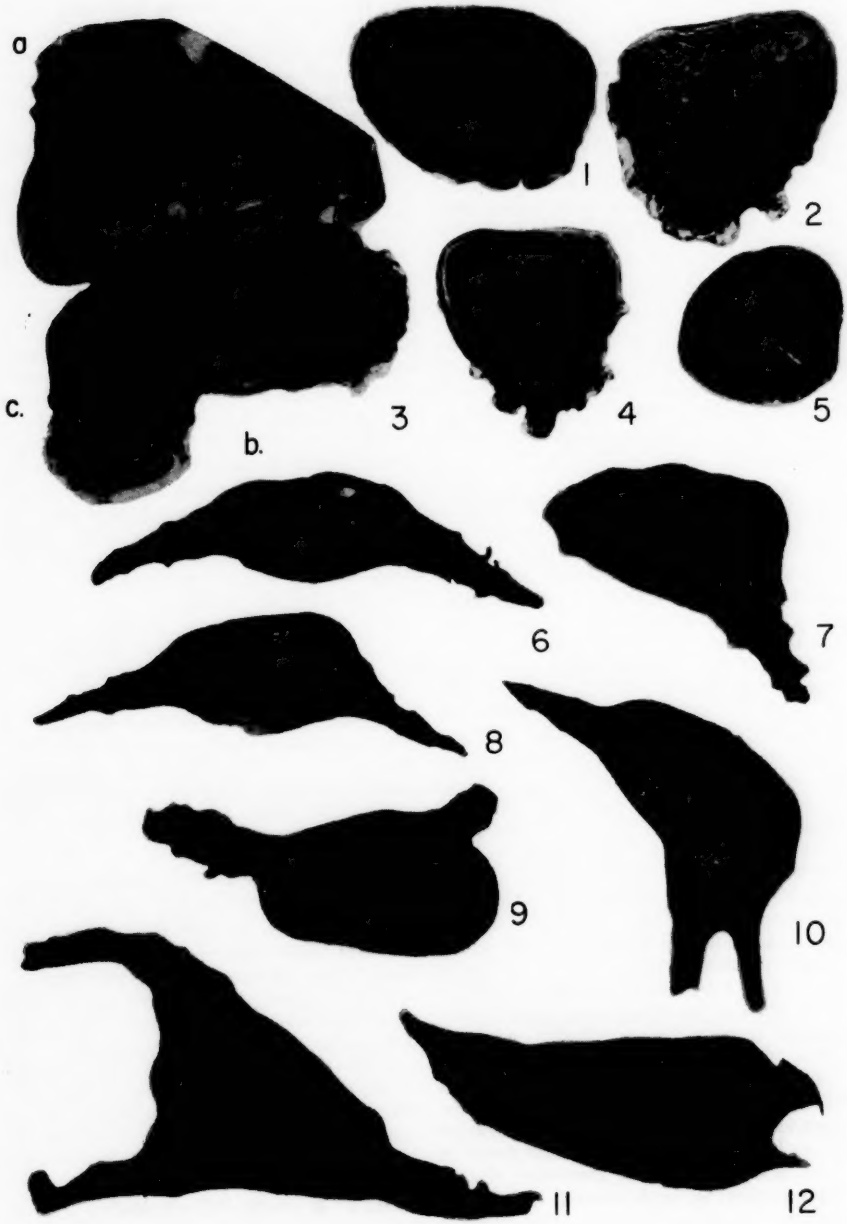
Spores monolete-triletoid, exine seemingly single-layered, distally thickened to form a coarsely verrucose protrusion; spore cavity ellipsoidal, its long axis generally at right angles to the polar axis of the spore; exine about 2 microns thick in the proximal portion; distal protuberance a thickened extension of the spore exine, shaped like a crown with large verrucose projections distally; exinal thickening beginning approximately at the equator but not appreciable except over the distal fifth of the spore cavity and beyond, size about a half of the total polar length of the spore, variable; laesurae variable, unmodified, individual specimens seemingly monolete, but distinctly trilete on individuals of one cluster, moderate in length, not reaching equatorial outline; spore body amber yellow, distal protrusion dark amber red; size 26–49 microns at right angles to the thickening, 35–64 microns parallel to the polar axis.

Occurrence.—Holotype: Imperial Island River No. 1, lat. 60°9′N., long. 121°8′W., 2133′ core, Banff formation (Tournaisian), Northwest Territories, western Canada. Slide 1—30, 3×120.0; spore cavity 31×46 microns, overall size 49×54 microns (Text-fig. 1—3a). Paratypes: associated specimens, 38×±58 microns overall (Text-fig. 1—3b) and 41×51 microns overall (Text-fig. 1—3c).

Illustrated specimens are from Imperial Grassy Lake No. 3, Alberta, 3858′ core. Slide 3–28.6×113.6; overall size 49×49 microns (Text-fig. 1—2). Same well, 3891′ core, slide 1–31.3×127.8, 37×49 microns overall (Text-fig. 1—1) Same well, 3904′ core, slide 1–29×109, spore cavity 24×37 microns, overall size 39×44 microns (Text-fig. 1—4).

Remarks.—*Torispora? tiara* is widespread in the Banff formation and its equivalents. The thickening is assumed to be distal, since on most specimens the laesurae are closely placed to the opposite end. In this respect the species differs from most specimens of *Torispora securis* and related species, where the thickening often seems lateral in posi-

TEXT-FIG. *1—1–4. Torispora? tiara* Staplin, n. sp., ×750. *1.* Reduced protrusion; *2,4,* typical forms; *3,* triletoid cluster, *a,* holotype, *b,c,* paratypes.
5. Crassosporites sp. A, ×750.
6–12. Cornispora varicornata Staplin & Jansonius, n. gen., n. sp., ×750. *6,* Holotype, monolete; *7,* single projection; *8,9,* triletoid; *10–12,* three projections.


a
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tion. Specimens with a much reduced thickening are rare.

Genus CORNISPORA Staplin & Jansonius, n. gen.

Spores monolete to triletoid; seemingly single-layered; characterized by one to four (possibly more) large thick cornate appendages or gibbosities in a lateral plane. Spore body laevigate, cornate appendages with cone-like spines or verrucosities in the single species.

Type species. Cornispora varicornata Staplin & Jansonius, n. sp.

Remarks.—The large lateral projections and the often distinct triletoid haptotypic structure distinguish *Cornispora* from *Torispora* Balme. In the latter, the single broad protuberance is closely appressed to the spore body.

CORNISPORA VARICORNATA Staplin & Jansonius, n. sp.
Text-fig. 1—6–12

Spores monolete or triletoid; seemingly single-layered; spore cavity generally reniform; usually with two large opposed horn-like slightly pendant exinal protrusions in the plane of the long axis of the spore cavity; spore sometimes dipper-shaped with one projection, sometimes subtriangular to wedge-shaped with a protrusion at each angle, rarely quadrate with four protrusions, one at each angle; protrusions much thickened, variable, usually long and tapering; exine laevigate except for variable irregular spinose to verrucose projections on the "horns"; laesurae unmodified, usually monolete but often triletoid, in which case two rays are short, form an acute angle with each other and oppose a longer ray, the whole roughly parallel to the long axis of the spore; spore wall 1.5–2 microns thick, "horns" much thicker, massive, color dark amber brown. Overall length 80–120 microns, width 21–34 microns.

Remarks.—Only individual specimens have been noted. The species is resistant to reworking of sediments and has been found in much younger beds (it was first noted in Triassic sediments by J. Jansonius). Specimens cannot be made clearly translucent without corroding the exine. The "horns" are extremely variable, one to four in number on the observed specimens. Associated with this species are subcircular trilete spores with an asymmetrical thickening of the exine, described here as *Crassosporites* sp. A. Whether the association is one of relationship or chance cannot be determined with the material at hand.

Occurrence.—Holotype: NTS (Canada) map sheet 95-K, lat.63°N., long.124°15′W., Northwest Territories, western Canada. Slide 3–22.5×125.3, spore body 24×38 microns, overall lateral extent 95 microns. Famennian stage, late Upper Devonian (Text-fig. 1—6).

Illustrated specimens are from NTS map 95-K, lat.62°40′N., long.124°W., Northwest Territories. Slide 4–39.2×124.7, overall size 26×97 microns (Text-fig. 1—8). Slide 4–33×120.2, overall length 97 microns (Text-fig. 1—12). Slide 4–34.5×115.9, overall length about 120 microns (Text-fig. 1—11). Slide 4–38.1×114.9, body about 31×54 microns (Text-fig. 1—7). Slide 2–29.1×122.9, overall length about 88 microns (Text-fig. 1—10). Slide 1–21.8×115, 32×54 microns excluding "horns" (Text-fig. 1—9).

Genus CRASSOSPORITES Alpern
Type species: *Crassosporites triletoides* Alpern, 1958

Spores with the combined features of *Punctatosporites* (ornamentation and elongate form), of *Torispora* (the thickening, much reduced), and of *Speciososporites* (sometimes possessing a cingulum). The type species is triletoid.

CRASSOSPORITES sp. A
Text-fig. 1—5

Spores subcircular in outline, asymmetrical, exine thickened irregularly, only slightly protruding; laevigate overall; two laesurae subequal in length, the third shorter and generally terminating where the exinal thickening begins; size 30–39 microns.

Occurrence.—NTS (Canada) map sheet 95-K, lat.63°N., long.124°15′W., Northwest Territories. Slide 5–26.2×111.2, 33×36 microns.

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MICROSPORES OF THE GENUS *MUROSPORA* SOMERS FROM MESOZOIC STRATA OF WESTERN CANADA AND AUSTRALIA

STANLEY A. J. POCOCK
Imperial Oil Limited, Calgary, Alberta

INTRODUCTION AND ACKNOWLEDGMENTS

Microspore assemblages from Mesozoic sediments of western Canada have yielded, in addition to generally recognized Mesozoic spore genera, a number of small trilete spores referable to the genus *Murospora* Somers, 1952. These spores are of considerable interest since the genus has previously been regarded as being confined to sediments of the Paleozoic era. Additional spores referable to the same genus were also recorded from basal Cretaceous (or possibly topmost Jurassic) assemblages from the Strathalbyn Sandstone of Western Australia. These spores appear to be identical to those described as *Cingulatisporites floridus* by Balme (1957). The possibility of the Canadian species being derived from the Paleozoic has been considered. However, since no recognized Paleozoic species from Canada resemble them and since their state of preservation and general appearance corresponds exactly to that of the microflora known to be in place, derivation is considered to be extremely improbable. The appearance and preservation of the Australian specimens would also suggest that the spores are not derived.

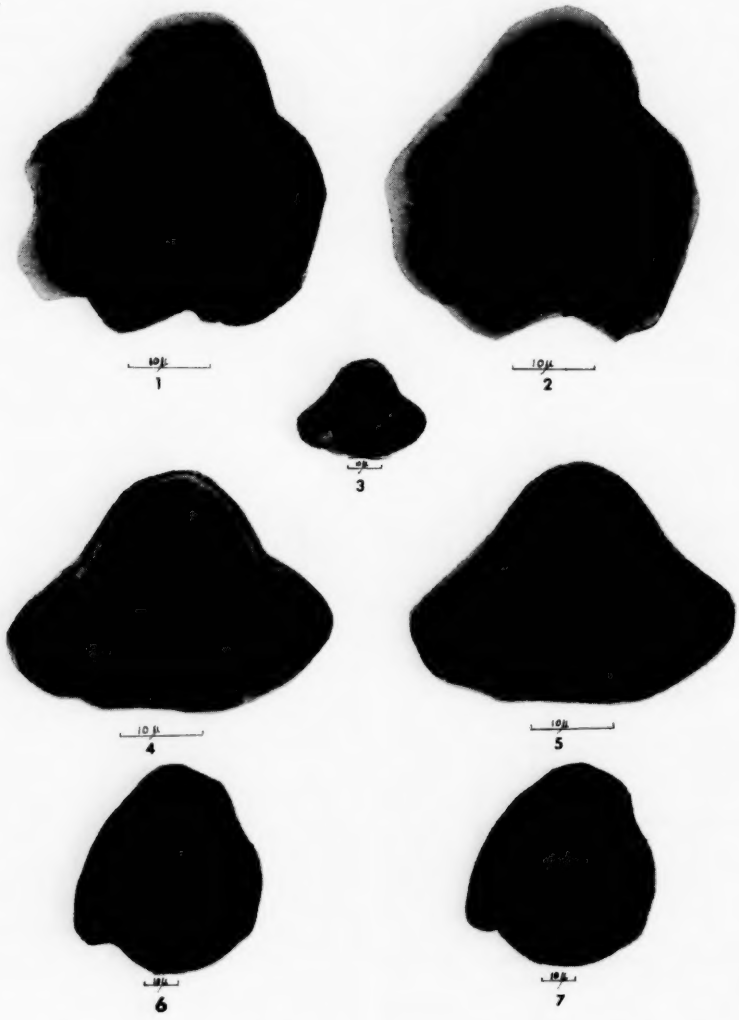
The author wishes to thank N. Elphinstone of Mobil Oil of Canada for the loan of slides and for permission to reproduce Text-fig. 1—6,7; B. E. Balme of the University of Western Australia for information concerning the species *Murospora florida;* F. L. Staplin and J. Jansonius for assistance in the compilation of data and criticism of the text; and Imperial Oil Limited for permission to publish this note.

SYSTEMATIC PALEONTOLOGY

Genus MUROSPORA Somers

Type species: *Murospora kosankei* Somers, 1952, Nova Scotia Res. Found., p. 20, fig. 13a.

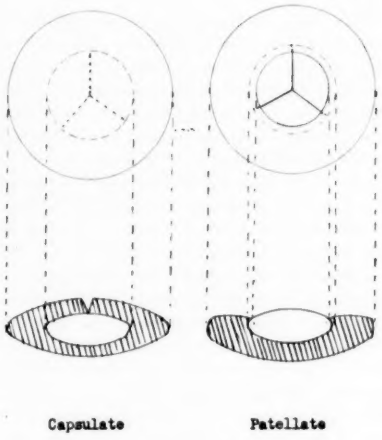
Specimens of *Murospora kosankei* (Text-fig. 1—1,2) from the type area and stratigraphic interval, Nova Scotia and New Brunswick, were provided by P. A. Hacque-



TEXT-FIG. *1—1,2. Murospora kosankei* Somers. *1*, Proximal and *2*, distal aspects of specimen from Mabou coal area, Cape Breton Island, Canada.
3–5. Murospora mesozoica Pocock, n. sp. *3*, Holotype, *4*, enlarged proximal, and *5*, distal aspects of same specimen.
6,7. Murospora florida (Balme). *6*, Proximal and *7*, distal aspects of specimen from Strathalbyn sandstone, Western Australia.

bard of the Geological Survey of Canada. It was found that the species is not cingulate, but consists of a spore body completely enclosed by a thick, tightly fitting outer structure, to which Staplin applied the term *capsula*. In his investigations of upper Mississippian spores from Western Canada several capsulate species were found, as well as spores with the thick outer structure confined to the distal and equatorial surfaces of the spore body. The term *patella* was applied to the latter structure, but because of the essential similarity in appearance to capsulate forms, patellate forms were also included in Staplin's diagnosis of *Murospora*.

If the type species of *Simozonotriletes* (*S. intortus*) is cingulate, no conflict exists with *Murospora*, but if it is capsulate or patellate (Text-fig. 2), *Simozonotriles* is a junior synonym of *Murospora*. *Westphalensisporites* Alpern, 1958, seems to be based on a species similar to *Murospora kosankei*.



TEXT-FIG. 2

MUROSPORA MESOZOICA Pocock, n. sp.
Text-fig. 1—3–5

Trilete microspores: laesurae simple slits extending the full radius of the central body; central body triangular, sides concave, apical angles rounded; proximal face scabrate; distal face enveloped by a smooth laevigate patella 3.5μ to 5μ wide; equatorial outline of patella parallels that of central body; diameter of spore 37μ (average); holotype 35μ; diameter of central body 23μ; holotype 22μ; spore colour dark brown.

Holotype.—Coop. Cypress Hills No. 1 Well, 14-2-3-25 W3M, 4670′–75′, Upper Vanguard Formation. Slide 2251-4 (37.0–124.1)

Range.—Upper Jurassic and Lower Cretaceous: Portlandian to Aptian.

Remarks.—Text-figure 1—3 illustrates the holotype and Text-figure 1—4,5 are enlarged proximal and distal views of the same specimen. The species was first found in highly calcareous shales of the Upper Vanguard formation (Jurassic: post-Kimmeridgian) of Southern Saskatchewan associated with such typical Jurassic species as *Classopollis classoides* Pflug, *"Zonalapollenites" dampieri* Balme, *"Z" trilobatus* Balme, *Klukisporites pseudoreticulatus* Couper, and *Eucommiidites troedssonii* Erdtman, as well as a few dinoflagellates and hystrichosphaerids which indicate that the shales were deposited in a shallow water marine environment. Recently further specimens assignable to the species have been recovered from the top of the glauconitic sand member of the Mannville formation (post-Neocomian-pre-Middle Albian: probably Aptian) which is a shallow marine deposit. None has been found in underlying Neocomian strata which are terrestrial in origin. This may be indicative of a coastal environment for the plant producing these spores, but may equally well be merely chance distribution of the species and the final answer must await the accumulation of more data regarding distribution.

MUROSPORA FLORIDA (Balme) *n. comb.*
Text-fig. 1—6,7

Cingulatisporites floridus BALME, 1957, Commonwealth Sci. Ind. Res. Org., Coal Res. Sec., T. C. 25, p. 26, pl. 5, figs. 60–61.

Trilete microspores; laesurae simple slits extending the full radius of the central body; central body triangular, sides concave to almost straight; apices rounded; proximal face scabrate; distal face enveloped by thick laevigate patella 8 to 15μ thick; spore outline triangular with irregular more or less straight sides; diameter of spores 66–79μ; average diameter of central body 33μ; spore colour dark brown.

Holotype.—Two syntypes were originally designated for this species by Balme, but since it is required under the International Rules of Botanical Nomenclature that one holotype be designated for valid publication of a species, it is necessary to assign one specimen as holotype for the species. It is, therefore, proposed, at Balme's suggestion, that the specimen illustrated by fig. 60 on his pl. 5, preserved on slide T.S.358, be regarded as holotype for the species.

Remarks.—Text-fig.1—6 and 7 illustrate typical specimens of *Murospora florida* from the Strathalbyn sandstone of Western Australia. They can be seen to have the same general structure as the Canadian species, but are considerably larger in size and more irregular in equatorial outline.

In the past, largely due to poor preparation techniques and inadequate optical equipment, there has been a tendency to regard spores and pollen grains as more or less two dimensional for purposes of description. Thus *Murospora* was originally described as cingulate and the outer structure of *Murospora "Cingulatisporites" florida* as a cingulum and not a patella. Improved preparation techniques and the use of oil immersion objectives in the examination of spores and pollen resulted in the determination of the true capsulate structure of *Murospora* and, as reported in the present paper, the patellate structure of *M. "Cingulatisporites" florida*. It appears probable that re-examination of Mesozoic spores referred to the genus *Cingulatisporites* under high magnification will reveal the need to transfer further species to the genus *Murospora*. Prior to the current paper, capsulate and patellate spores had been reported only from Paleozoic sediments, although similar structures are known to occur in spores of some recent plant genera (e.g., *Lophosoria* & *Taenitis*). Detailed examination of Mesozoic spore-pollen assemblages by the author indicates, however, that such structures are just as commonly found in Mesozoic as in Paleozoic spores. There is no evidence to suggest that the various species are in any way genetically related.

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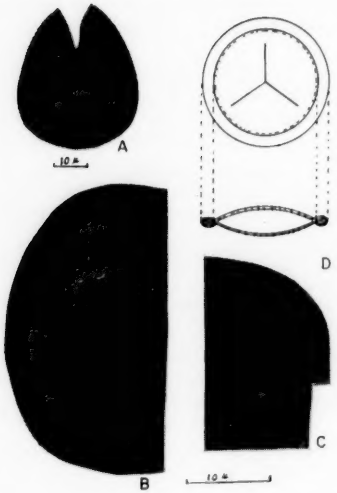
THE MICROSPORE GENUS *CINGULATISPORITES* THOMSON, 1953

STANLEY A. J. POCOCK
Imperial Oil Limited, Calgary, Alberta

INTRODUCTION

In a note on patellate microspores of Mesozoic age the author (Pocock, 1961) described some microspores in which an equatorial rim forms part of a continuous structure enveloping distal or both hemispheres ("patella" or "capsula" respectively) of the spore body. He contended that spores exhibiting such structure should not be included in the genus *Cingulatisporites* Thomson, 1953. A number of palynologists have questioned this comment on the grounds that the genotype of *Cingulatisporites* (*C. levispeciosus* Pflug, 1953) may itself be patellate. In order to settle this point and in view of the fact that spores of numerous morphological types, some apparently bearing little resemblance to the genotype, have been assigned to the genus *Cingulatisporites*, it has been considered desirable to examine the type species and amplify the generic diagnosis from the data obtained.



TEXT-FIG. 1*A*,*B*—*Cingulatisporites levispeciosus* Pflug. Proximal view of whole specimen (*A*) and enlarged view of part of same specimen showing attachment of cingulum to spore body (*B*).
C—*Cingulatisporites levispecious* Pflug. Detail of a portion of another specimen showing cingulum torn cleanly away from spore body.
D—Diagram illustrating the structure of *Cingulatisporites* (proximal view and polar section).

H. I. Pflug kindly sent me a cotype of *Cingulatisporites levispeciosus* and other specimens of the same species from the type locality (the Paleocene brown coal of Wehmingen, Hannover, Germany). He also supplied his comments on the species.

MORPHOLOGY

Pflug (personal communication) interprets *Cingulatisporites levispeciosus* as a microspore with a single layered central body surrounded equatorially by an appended equatorial rim or "cingulum." He does not regard the equatorial structure as the equatorial expression of a "patella" or "capsula," or as a zone where the distal and proximal exinal layers are apressed and, possibly, slightly thickened ("limbate"). He considers that the exinal ornament varies from smooth to scabrate, not always smooth as stated in the original description.

Examination of the cotype and additional specimens of *Cingulatisporites levispeciosus*, using an oil immersion objective, indicates that Pflug's interpretation is, in all probability, correct. The photograph of the cotype (Text-fig. 1B) shows features (X−X and X′−X′) which indicate thinning where the equatorial structure is attached to the central body, and support the theory that the structure is distinct and appended. A portion of another specimen (Text-fig. 1C) also supports this contention, showing a portion of the cingulum broken cleanly away from the central body.

The species therefore seems to be truly cingulate, a cingulum being here defined as an appended equatorial rim disposed symmetrically with relation to the equatorial plane; the attachment to the central body being relatively narrow in polar view (Text-fig. 1D). This redefinition of the term cingulum is intended to restore its original meaning (cf. Potonie & Kremp, 1955), since a present tendency of palynologists to regard it as "a flange-like extension of the exine around the equatorial region of a spore" (Couper 1958) is far too broad for practical use.

SYSTEMATIC PALEONTOLOGY

Genus CINGULATISPORITES Thomson

Cingulatisporites THOMSON, 1953 (*in* Thomson and Pflug), Palaeontographica, 94B, p. 58, pl. 1, fig. 16.

Trilete microspores; laesurae extending towards, but not onto the cingulum; exine single layered, smooth, scabrate or granulose, never strongly ornamented; equatorial outline rounded triangular; spore body surrounded equatorially by a narrow cingulum (less than $\frac{1}{8}$ of the greatest spore diameter).

CINGULATISPORITES LEVISPECIOSUS Pflug

Trilete; laesurae simple slits each over $\frac{3}{4}$ radius of central body; exine relatively thin, single layered, smooth to scabrate; equatorial outline rounded triangular; spore body surrounded equatorially by a narrow cingulum; spore colour light yellow, total diameter of spore 30–60μ; width of cingulum 2–4μ.

Remarks.—The above diagnosis and description are in no way intended to emend the genus *Cingulatisporites*. They are merely an amplified restatement of the essential characters exhibited by the genotype which must be regarded as the morphological characters which define and hold together all members of that genus. The generic diagnosis corresponds closely with that given by Potonie (1956) and cited by him as an emendation, although, since it does not alter the interpretation of the genus in any way, it must be considered a redescription and not a true emendation.

Cingulate spores are by no means common. From a two-dimensional standpoint, structures that look cingulate occur in many genera but, in the solid, they are found to be flanges of one type or another, or thickened ektexinal structures (capsula, patella, etc.).

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CTENOGNATHODUS FAY, 1959 OR *SPATHOGNATHODUS* BRANSON & MEHL, 1941?

WILLI ZIEGLER

Geologisches Landesamt Nordrhein-Westfalen, Krefeld, Germany

When Pander published the first conodont article in 1856, he introduced the generic name *Ctenognathus*. Under this name he united four species of very different morphologic features: *murchisoni, verneuilli, kayserlingii*, and *obliquus* (1856). Today it is clear that Pander's four species belong to several different conodont genera.

Pander did not designate a type species for the genus, but *Ctenognathus murchisoni* was the first species he described. Ulrich & Bassler (1926) and Holmes (1928) assumed that the first species would be the type species and so listed *C. murchisoni* as the genotype.

When Branson & Mehl (1933) established their new genus, *Ozarkodina*, they remarked:

> "The genus *Ctenognathus* was proposed by Pander to include several forms from the Silurian and Devonian clearly not closely related. If the first species described, *C. murchisoni*, be taken as the genotype the genus cannot be identified with certainty because the units figured were fragmental. Some of the specimens described by Pander as *C. verneuelli* [sic!] seem to belong to our genus, *Ozarkodina*."

Stauffer (1938) published several species under the name *Ctenognathus*, all of which are now considered to belong to *Ozarkodina*. Ellison (1946) partly classified *Ctenognathus* Pander as a senior synonym of *Ozarkodina*.

The redesignation of the genotype *Ctenognathus murchisoni* in Fay (1952) directed the attention of many of the younger writers to the close relationship between *Ctenognathus* Pander and *Spathognathodus* Branson & Mehl, 1941 (= *Spathodus* Branson & Mehl, 1933, preoccupied by *Spathodus* Boulenger, 1900). It suddenly became obvious that *C. murchisoni* was based on the same generic features that are shown in the type species, *S. primus*, of *Spathognathodus* Branson & Mehl, 1941.

This, and the fact that his material came from nearly the same locality as the specimens described by Pander, led Gross (1954), e.g., to the conclusion that *Spathognathodus* Branson & Mehl is a junior synonym of *Ctenognathus* Pander. Gross went a step further and proposed a neotype for *C.*

murchisoni, if it would become apparent that Pander's original material does not exist:

> "Sollte das von Pander auf Taf. 4, Fig. 17a abgebildete Stück nicht mehr vorhanden sein, so tritt an seine Stelle als Neotypus das hier auf Taf. 1, Fig. 9 wiedergegebene Stück."

This method of designating a neotype is in conflict with the provisions of the Rules. It is based conditionally (Rud. Richter, 1938). K. J. Müller followed Gross and regarded (1956) *Spathognathodus* a junior synonym of *Ctenognathus*.

It was W. H. Hass of the U. S. Geological Survey, Washington, D. C., who for the first time pointed out that *Ctenognathus* Pander, 1856, was preoccupied by *Ctenognathus* Fairmaire, 1843. In a letter of September 30, 1958 to the writer, Hass recorded:

> "It is my opinion that the name [*Ctenognathus* Pander, 1856] is invalid. According to Neave (1939), Nomenclator Zoologicus, vol. 1, p. 896, and the Nomenclator annimalium generum et subgenerum, vol. 2 (C-E), p. 853, 1929. L. Fairmaire proposed the name *Ctenognathus* in 1843 for a genus of the Coleoptera. I checked Fairmaire's paper which was published in the Ann. Soc. ent. France, ser. 2, vol. 1, p. 13, 1843, and believe that his name is valid. Hence, I therefore consider *Spathoganathodus* Branson & Mehl 1941 to be a valid name."

The writer (Ziegler, 1960) therefore stated that the name of the junior synonym *Spathognathodus* is the only valid one for these conodonts formerly published under *Ctenognathus* Pander, 1856, the type of which is *C. murchisoni*, and for those fitting the generic description of Branson & Mehl's genus *Spathognathodus*.

In 1959 Fay compiled some conodont homonyms in a short note which had not been known to the writer before completing his paper (Ziegler, 1960). Fay also suggested the homonymy of *Ctenognathus* Pander, 1856, and *Ctenognathus* Fairmaire, 1843, and proposed a new name for *Ctenognathus* Pander = *Ctenognathodus* the type species of which is *C. murchisoni* Pander. The new name by Fay, however, must be considered a junior subjective synonym of *Spathognathodus* Branson & Mehl, 1941, and therefore has to be regarded invalid. *The only valid name of the genus which includes the generic features of these conodont species to be placed around* Ctenognathus murchisoni *Pander must be* Spathognathodus *Branson & Mehl, 1941, the type species of which is* C. murchisoni *Pander, 1856.*

I am most grateful to O. Kraus, Senckenberg-Museum, Frankfurt/Main, Germany, for nomenclatorial help, and Wo. Schmidt, Geologisches Landesamt, Nordrhein-Westfalen, Krefeld, Germany, for advisory help. I also wish to appreciate the kindness of the deceased W. H. Hass, who discussed many conodont problems with the author by letter and thus always gave great help. I am indebted to S. P. Ellison who read the manuscript and gave advice.

A list of all conodont species, formerly described as *Ctenognathus*, *Mehlina*, and *Pandorina* is given below, followed by the names which are now regarded valid;

Ctenognathus kayserlingii Pander, 1856 (pl. 2A, fig. 15) = seems to belong to *Trichonodella* or *Lonchodina*.

Ctenognathus murchisoni Pander, 1856 = *Spathognathodus murchisoni* (Pander, 1856).

Ctenognathus obliquus Pander, 1856 = *Hindeodella obliqua* (Pander, 1856).

Ctenognathus verneuilli Pander, 1856 = *Ozarkodina verneuilli* (Pander, 1856) (pl. 2A, figs. 16,17); the specimen figured on pl. 4, fig. 18 seems to belong to *Spathognathodus* or *Ozarkodina;* fig. 13, pl. 2A seems to belong to *Lonchodina;* and fig. 14, pl. 2A to *Trichonodella* or *Lonchodina.*

Ctenognathus conservativa Müller, 1956 = *Spathognathodus conservativus* (Müller, 1956).

Ctenognathus deparcus Stauffer, 1938 = *Ozarkodina deparca* (Stauffer, 1938).

Ctenognathus discreta Müller, 1956 = *Spathognathodus discretus* (Müller, 1956).

Ctenognathus elegans Stauffer, 1938 = *Ozarkodina elegans* (Stauffer, 1938).

Ctenognathus falcatus Stauffer, 1938 = *Ozarkodina falcata* (Stauffer, 1938).

Ctenognathus falsiformis Stauffer, 1938 = *Ozarkodina falsiformis* (Stauffer, 1938).

Ctenognathus firmus Stauffer, 1938 = *Ozarkodina firma* (Stauffer, 1938).

Ctenognathus pseudofissilis Lindström, 1959 = *Spathognathodus pseudofissilis* (Lindström, 1959). [In an afterwards published errata-sheet to his paper "Conodonts of the Crug limestone (Ordovician, Wales)," Micropaleontology, 5, p. 427–452, Lindström pointed out that the name *Ctenognathus* which he used in his paper is invalid and *Spathognathodus* is valid instead.]

Mehlina gradatus Youngquist, 1945 = *Spathognathodus gradatus* (Youngquist, 1945).

Pandorina insita Stauffer 1940 = *Spathognathodus insitus* (Stauffer, 1940).

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REVISION OF "*PROTEONINA DIFFLUGIFORMIS*"

HUBERT C. SKINNER

Tulane University, New Orleans, Louisiana

The foraminifer known as "*Proteonina difflugiformis*" is widely distributed through Cretaceous and younger deposits. The wall structure of the agglutinated test varies. It may be composed of varied sizes of quartz sand grains, of sponge spicules, or of the tests of smaller calcareous foraminifera.

H. B. Brady in his original description of the species (1879) did not designate the type locality, but recorded the form from the North Atlantic, the South Atlantic, and the South Pacific at depths ranging from 1900 to 2740 fathoms. In 1884 he stated that:

> "The structure of the test varies with the locality and the nature of the sea bottom. The walls are often composed of fine siliceous grains very neatly joined together, as in figures 1, 2, 3; sometimes they are beset with projecting sponge-spicules, as in figure 4; but more frequently, especially in northern habitats where the species is most plentiful, the test is constructed of coarse sand and has a very rough exterior, as shown in figure 5."

Brady reported the form from numerous stations, including latitudes to nearly 80° north and depths to 3950 fathoms.

Other authors have made similar references to the species. Phleger & Parker (1951) observed that specimens from deep water samples are more finely arenaceous than those from shallow water, and that the species is widespread from the Arctic to the South Atlantic from depths of 7 meters to 4500 meters. Parker (1952) describes the coarsely arenaceous form as "a common one south of Cape Cod" and further states that it "also occurs in the Arctic" and "is the more common form in northern waters of the Atlantic."

The present writer considers that "*Proteonina difflugiformis*" is a single biologic species belonging to the genus *Reophax*, as originally defined by H. B. Brady. It seems clear that the structure of the test wall varies according to the character of the substrate, the water depth, and the latitude. Thus, to preserve the species, *Reophax difflugiformis* is herein redefined. The distinctive forms differing from the typical only in the structure of the test wall are designated subspecies.

Acknowledgments.—The writer is indebted to Dr. H. E. Vokes for invaluable assistance in taxonomic problems and for making available the galley proofs of the new International Code of Zoological Nomenclature which is now in press.

SYSTEMATIC DESCRIPTIONS

Order FORAMINIFERIDA Zborzewski
Superfamily LITUOLACEA Lamarck
Family ASCHEMONELLIDAE
Eimer & Fickert
Subfamily REOPHACINAE Cushman
Genus REOPHAX Montfort

Reophax MONTFORT, 1808, Conch. Syst., v. 1, p. 331.

Type species: *Reophax scorpiurus* Denys de Montfort, 1808

Test free, elongate, consisting of a rectilinear or curved series of undivided chambers; wall agglutinated, composed of sand grains, mica flakes, sponge spicules or other foraminifers, firmly cemented on a chitinous base; aperture simple, terminal, in some species elevated on a short neck.

Discussion.—*Proteonina fusiformis* Williamson, the type species (subsequent designation, Rhumbler, 1904, p. 244) of *Proteonina* Williamson, 1858, has been shown to be multilocular (Brady, 1884; Loeblich & Tappan, 1955), and *Proteonina* has been suppressed (Loeblich & Tappan) as a junior synonym of *Reophax* Montfort.

REOPHAX DIFFLUGIFORMIS H. B. Brady

Reophax difflugiformis H. B. BRADY, 1879, Quart. Jour. Micros. Sci., v. 19, p. 51, pl. 4, figs. 3a, b.
?Haplophragmium lagenarium BERTHELIN, 1880, Soc. Géol. France, Mém., sér. 3, tome 1, no. 5, p. 21, pl. 1, figs. 2a,b.
Reophax difflugiformis, H. B. BRADY, 1882, Royal Soc. Edinburgh, Proc., v. 11, p. 715.
Reophax difflugiformis H. B. BRADY, 1884, Challenger, Rept., Zoology, v. 9, p. 289, pl. 30, figs. 1–3.
Proteonina difflugiformis lagenarium MILLETT, 1899, Royal Micros. Soc., Jour., p. 253.
Protenina difflugiformis-lagenarium RHUMBLER, 1904, Archiv. Protistenk., v. 3, p. 246, fig. 80c.
Proteonina difflugiformis RHUMBLER, 1904, Archiv. Protistenk., v. 3, p. 245.
Proteonina difflugiformis CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 15.
Reophax difflugiformis BARKER, 1960, Soc. Econ. Pal. Mineralogists, Spec. Pub. 9, p. 62, pl. 30, figs. 1–3.

Test free, a single, undivided chamber, rounded or oval in transverse section; wall agglutinated, composed of fine quartz grains firmly cemented on a chitinous base, exterior nearly smooth; aperture simple, terminal, elevated on a short produced neck.

Discussion.—This is a widely distributed species, ranging from the Cretaceous to the Recent. The holotype has a finely arenaceous test and *Reophax difflugiformis difflugiformis* is here restricted to the fine-grained form.

REOPHAX DIFFLUGIFORMIS SPICULATA Skinner, subsp. nov.

Reophax difflugiformis H. B. BRADY, 1884, Challenger, Rept., Zoology, v. 9, p. 290, pl. 30, fig. 4.

This form differs from the typical subspecies in that the test is larger and the wall is set with projecting sponge spicules.

REOPHAX DIFFLUGIFORMIS ARENULATA Skinner, subsp. nov.

Reophax difflugiformis H. B. BRADY, 1884, Challenger, Rept., Zoology, v. 9, p. 290, pl. 30, fig. 5.
Reophax difflugiformis FLINT, 1899, U. S. Nat. Mus., Rept. (for 1897), pt. 1, p. 272, pl. 16, fig. 2.
Proteonina difflugiformis CUSHMAN, 1946, U. S. Geol. Survey, Prof. Paper 206, p. 15, pl. 1, figs. 7,8.
Proteonina atlantica PARKER, 1952, Harvard Mus. Comp. Zool., Bull., v. 106, no. 9, p. 393, pl. 1, fig. 2. (*non* Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 5, pl. 1, fig. 4.)
Proteonina atlantica BANDY, 1953, Jour. Paleontology, v. 27, p. 177, pl. 21, figs. 5a,b. (*non* Cushman, 1944.)
Proteonina difflugiformis FRIZZELL, 1954, Texas Bur. Econ. Geol., Univ. Texas, Rept. Inv. 22, p. 57, pl. 1, fig. 4.
Reophax atlantica BARKER, 1960, Soc. Econ. Pal. Mineralogists, Spec. Pub. 9, p. 62, pl. 30, fig. 5.

This form differs from the typical subspecies in that the test is larger and the wall is composed of relatively coarse sand grains. The neck is less pronounced in many specimens but others have been seen that have a quite prominent neck (Flint, 1899, pl. 16, fig. 2).

Discussion.—Parker placed this form in synonymy with *Reophax atlantica* (Cushman), which Cushman described as "without a distinct neck, but gradually contracted toward the apertural end." Parker's assignment is not followed. It is probable that the

neck is partially obscured on some specimens due to the coarse nature of the wall. *Reophax atlantica* (Cushman) is restricted to forms agreeing with the holotype and showing no evidence of a produced neck, but rather a rounded apex.

Bandy (1953) also reports this form from 400–700 feet off California.

REOPHAX DIFFLUGIFORMIS TESTACEA Flint

Reophax difflugiformis testacea FLINT, 1899, U. S. Nat. Mus., Rept. (for 1897), pt. 1, p. 273, pl. 16, fig. 1.

"Identical with the preceding [*R. difflugiformis* Brady], except that the test is much larger and composed entirely of small empty shells of foraminifera. Section shows the undivided chamber and the walls constructed of a single layer of shells."

Discussion.—This subspecies agrees in form with the holotype of *Reophax difflugiformis* and appears to differ only in the character of the wall structure. It was reported by Norton (1930) from 687 fathoms in the Lesser Antilles.

Type Locality.—Southward of Long Island (Albatross station 2234), 810 fathoms.

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A NEW SPECIES OF TRILOBITE FROM THE KIMMSWICK LIMESTONE (ORDOVICIAN) OF MISSOURI

GEORGE C. ESKER III
Washington University, St. Louis, Missouri

INTRODUCTION

The discovery of a cranidium of a cheirurid trilobite from the Kimmswick limestone led to this investigation. It was noted in checking Bradley's work on the Kimmswick fauna and the faunal list of the Kimmswick limestone in Branson's *Geology of Missouri*, that the cranidium was not listed. Examination of Bradley's type specimens, which are closely related to the recently discovered cranidium from the Kimmswick limestone, showed that Bradley's type specimens were misidentified. Bradley's description is emended and a new species of *Acanthoparypha* Whittington & Evitt (1953) is erected.

Discussion.—Bradley published his fauna of the Kimmswick limestone in 1930. He described a small cheirurid trilobite from the formation and placed it in the genus *Pseudosphaerexochus* Schmidt (1881). Branson in his *Geology of Missouri* listed *Pseudosphaerexochus subcircularis* Bradley and *P. trentonensis* Clarke as occuring in the Kimmswick fauna. It is doubtful however, that this species is present in the Kimmswick because almost all of the species of trilobites of the Kimmswick limestone are distinct from those of other rocks of Trenton age, though many are closely related. The present investigation showed that neither *P. subcircularis* nor *P. trentonensis* belong in the genus *Pseudosphaerexochus*, and both species differ from the cranidium described here. The examination of Bradley's three type specimens of *P. subcircularis* showed that they belong to the genus *Acanthoparypha* Whittington & Evitt (1953). In addition the study of Bradley's holotype and paratypes showed that two of the specimens were alike but that the third was distinct from the other two. The holotype and one paratype are the same species and are here referred to *Acanthoparypha subcircularis* (Bradley). These are two glabellas. The third specimen is a partial cranidium showing the left cheek and part of the glabella. The general shape of the glabella of this species differs from the holotype and the other paratype. Unfortunately neither the holotype nor the one paratype has any part of the cheek preserved. These specimens differ from the third specimen in that the glabella curves more strongly and begins to curve nearer to the posterior of the glabella. Therefore, it is suggested here that the description of the cheek of *A. subcircularis* is invalid. This description was based on the third specimen which appears to be another species but is too poorly preserved for an accurate description. The three specimens belong to the genus *Acanthoparypha* because of the glabellar features and in the third specimen the cheek is also distinctive of the genus.

Acknowledgments.—I am indebted to Dorothy Jung Echols for her help in preparing and reviewing this article; to Matthew H. Nitecki, Curator of the Walker Museum, for the loan of Bradley's type specimens; to Harriet Long, Librarian of the Department of Geology of Washington University, for her aid in obtaining literature; and to Terry Eppler for taking the photographs.

SYSTEMATIC DESCRIPTION

Genus ACANTHOPARYPHA
Whittington & Evitt
ACANTHOPARYPHA PROJECTA
Esker, n. sp.
Text-fig. 1

Material and Locality.—One fragmentary cranidium from the Upper Middle Ordovician Kimmswick limestone at the Goetz Quarry at Glen Park near Barnhart, Missouri.

Description.—Glabella almost circular in outline, very nearly as wide as long, evenly convex. There are three pairs of glabellar furrows. The third pair are short and nearly straight, starting well foward on the glabella and extending inward and backwards at an angle of about 45° with the axis. The second pair are larger and much more curved. The first pair are the longest, being

A

B

TEXT-FIG. *1*—*A,B. Acanthoparypha projecta* Esker, n. sp. *A*. Dorsal view of the fragmentary cranidium. *B*. Anterior view of same specimen as *A*. Both are from the Kimmswick limestone at the Goetz Quarry near Barnhart, Missouri. Both are of the holotype, ×1.

nearly parallel to the third pair before curving strongly backwards, extending nearly to the summit of the glabella, and connected with the occipital furrow by a slight shallow depression. All Glabellar furrows are equally incised and of similar width. The profile across the third lobes is almost a semicircle, profile across the first lobes or basal lobes, shows sides flattened and rising to rounded crest. The glabella projects to the rear at the median crest and curves forward slightly until it reaches the sides. The fixed cheeks are small. The facial suture reaches the lateral margin at almost a right angle to the axis but slightly inclined towards the posterior. The entire cephalon is bounded by a narrow convex border which is produced into spines at the genal angles. A small spine is located on the border slightly anterior to the genal angle in addition to the genal spine. The surface of the cheeks is abundantly pitted; that of the glabella is smooth with the exception of a few small scattered pustules.

Dimensions.—Length of glabella 20 mm. Width of glabella 19 mm.

Affinities.—*Acanthoparypha projecta* is close to *A. chiropyga* Whittington & Evitt, *A. subcircularis* (Bradley), and *A. perforata* Whittington & Evitt. It may be distinguished from these species by shape of the glabella and glabellar furrows. In *A. projecta* the posterior portion of the glabella projects to the rear at the crest of the glabella. In this respect it differs from all known species of *Acanthoparypha*. The other species are almost straight across the occipital furrow except that they have two slight indentations on the posterior edge of the glabella opposite the end of the basal glabellar furrows where they curve back towards the occipital furrow.

Repository.—The author's private collection.

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CONCAVICARIS AND *QUASICARIS*, SUBSTITUTE NAMES FOR *COLPOCARIS* MEEK, 1872, AND *PTEROCARIS* BARRANDE, 1872

W. D. IAN ROLFE
Museum of Comparative Zoölogy, Cambridge 38, Massachusetts

Two phyllocarid crustacean nominal genera which are junior homonyms of decapod crustacean genera require substitute names. *Colpocaris* Meek, 1872 (Proc. Acad. Nat. Sci. Philadelphia, v. 23, p. 332) is preoccupied by *Colpocaris* von Meyer, 1862 (Palaeontographica, v. 10, p. 163—Brachyura) and the name *Concavicaris* is proposed as a substitute. The new name is a feminine noun, compounded from *concavus*, referring to the concave nature of the posterior carapace margin, and *caris*, the Latin word for shrimp.

Pterocaris Barrande, 1872 (Systême Silurien du Centre de la Bohême, Supplément au Vol. 1, Prague and Paris, p. 464) is a junior homonym of *Pterocaris* Heller, 1862 (Sitzungsber. der Kaiserlich. Akad. der Wiss., Math.-naturwiss. Cl., Wien, Bd. 45, Abt. I, p. 395—Caridea) and the substitute name *Quasicaris* is proposed. The Latin prefix of this compound feminine name means "simulating," or "appearing as if," and refers to the doubtful nature of this rare fossil. The nominal genus *Pterocaris* Claus, 1876 (Untersuchungen zur Erforschung der Genealogischen Grundlage des Crustaceen-Systems, Wien, p. 65—larval brachyuran) is a second junior homonym. Since such "larval genera" are objectionable (Gurney, R., 1950, Proc. Zool. Soc. Lond., v. 119, p. 806), it seems preferable to propose no substitute name.

JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1244–1245, NOVEMBER, 1961

REVIEWS

PALEOZOIC SPECIES OF *BAIRDIA* AND RELATED GENERA, by I. G. SOHN. U. S. Geological Survey, Professional Paper 330-A, 1960, 105 p., 15 figs., 6 pls. U. S. Government Printing Office, $1.00.

This paper, which is part of a continuing synthesis of current knowledge of upper Paleozoic ostracode genera, is a restudy of Paleozoic species of *Bairdia* and related genera. The assignment of more than 200 species of Paleozoic age to the genus *Bairdia*, combined with the fact that most of the species belonging to this genus have smooth carapaces without distinct ornamentation, has led to considerable nomenclatural confusion in the classification of *Bairdia*. The present effort to clarify and bring up to date our knowledge of *Bairdia* will be welcomed not only by students of the Paleozoic, but by all students of ostracodes, because this genus or related genera have remained abundant since the Paleozoic and are found in the present oceans.

In order to be able to review the numerous species assigned to *Bairdia* in a systematic manner, a punched card system was devised with each card containing morphological characteristics and other information obtained from descriptions of *Bairdia* in the literature. By providing a semi-objective method of evaluating the importance of carapace characters, the punched cards were helpful in subdividing the genus *Bairdia*, and in making identification keys to the genera and species considered in the study.

Paleozoic species of the genus *Bairdia* are referred to the following genera: *Bairdia* McCoy, *Cryptobairdia* Sohn, *Rectobairdia* Sohn, *Bairdiacypris* Bradfield, *Fabilicypris* Cooper, *Orthobairdia* Sohn, *Pustulobairdia* Sohn, *Ceratobairdia* Sohn, *Bairdiolites* Croneis & Gale, *Rishona* Sohn, *Bekena* Gibson, and others. A total of 71 species of *Bairdia* are recognized; two of these are new. Twenty-one species, listed as *Bairdia* sp. A to U, are considered as misidentified specimens probably representing undescribed species. Seventy-four species are listed as doubtful and indeterminate. Six new names are proposed to replace junior homonyms, and seven junior homonyms were noted but not renamed. Over 350 names are listed as either synonyms or rejected species of *Bairdia*.

An interesting observation of Sohn's is that a considerable number of descriptions of ostracode species have been based on internal casts. Although genera based on such species are valid, they make classification difficult, especially if they are not recognized as internal casts. He lists five criteria for recognizing internal ostracode casts. These criteria should be very helpful for identifying the internal casts of species of other genera as well as those belonging to *Bairdia*.

A section concerning the application of zoological nomenclature to ostracode classification, with illustrated examples, will be most useful to beginning students of paleontology and as a reference for more experienced taxonomists.

Sohn states (p. 13) that, "The living species of *Bairdia* as conceived by Müller and subsequent workers and the post-Paleozoic fossil species referred to *Bairdia* are very likely not congeneric with the Paleozoic species of *Bairdia* McCoy, 1844, and require one or more new genera for their reception," and suggests criteria of carapace shape, hingement, denticulate margins, and presence of ventro-terminal loculae for separating the groups. The present paper, which brings together in a single publication our present knowledge of Paleozoic *Bairdia*, will enable students working with post-Paleozoic *Bairdia* to compare readily their specimens with Paleozoic species, and thus discern more easily any differences that might be used to distinguish new genera. I think that carapace internal microstructure might be added to Sohn's list of criteria that might be used to subdivide *Bairdia*.

The straigrapher will welcome the complete geographic and stratigraphic data given for each species, and also the numerous tables and figures showing the range and frequency distribution of species of *Bairdia* and related genera. The stratigraphic range of *Bairdia*, as redefined, is restricted to rocks of Middle Devonian to Permian age.

Sohn has reproduced (p. 14) the original figure of *Nesidea* Costa, 1849. *Nesidea* has

been used by several students in place of *Bairdia* for post-Paleozoic and living forms. Most students, however, have considered *Nesidea* to be a synonym of *Bairdia*. Sohn raises several objections to including *Nesidea* among the Ostracoda. In view of these objections it is probably best to consider *Nesidea hirta* as a doubtful species.

In addition to the review and revision of *Bairdia*, the following Paleozoic genera are treated in a similar manner in this paper: *Silenites* Coryell & Booth, *Tubulibairdia* Swartz, *Phanassymetria* Roth, *Pachydomella* Ulrich, *Spinobairdia* Morris & Hill, and *Bairdiocypris* Kegel. A new family Rishoniidae is erected to include *Rishona* Sohn and *Samarella* Polenova.

The major contribution of this paper is its compilation of current knowledge of Paleozoic *Bairdia*. As paleontological classification is a highly subjective discipline, it is likely that some specialists will follow Sohn's classification and others will not. But regardless of the specialist's views, he will be able to arrive at a decision more easily as a result of I. G. Sohn's monograph.

LOUIS S. KORNICKER
Agricultural and Mechanical College of Texas

BIBLIOGRAPHIE STRATIGRAPHISCH WICHTIGER MIKROPALÄONTOLOGISCHER PUBLIKATIONEN VON ETWA 1830 BIS 1958 MIT KURZREFERATEN, by HEINRICH HILTERMANN. E. Schweitzerbart'sche Verlagsbuchhandlung (Nägele & Obermiller), Stuttgart, 1961, 5 parts, p. i-v, 1–403. Price DM 94 (approx. $23.50), or DM 18,80 (approx. $4.70) for each part.

Contents: Part 1, Preface, textbooks and manuals, general micropaleontology, bionomics (reference no. 1–195), methods (no. 196–300), stratigraphy of Cambrain-Devonian (no. 301–560), Carboniferous and Permian (no. 561–727). Part 2, Stratigraphy of Carboniferous and Permian (no. 728–944), Triassic (no. 945–996), Jurassic (no. 997–1293), Cretaceous (no. 1294–1459). Part 3, Stratigraphy of Cretaceous (no. 1460–1893), Tertiary (no. 1894–2207). Part 4, Stratigraphy of Tertiary (no. 2208–2958), Quaternary (no. 2959–2979). Part 5, Stratigraphy of Quaternary (no. 2980–3137), bibliographies (no. 3138–3210), authors' index, subject and locality index.

The vast amount of literature on micropaleontology is dispersed through many periodicals, which together are available in only a few libraries. No one has been able with convenience to keep track of the proceedings of the entire field. Therefore, bibliographies which make readily available the references of published information have been assembled for various groups of fossils. Their publication is advantageous for all students in the field, and they often stimulate research in a group. This fact was demonstrated recently by Ash (Micropaleontology v. 7, p. 214, fig. 1). As a result of the publication of Fay's catalogue of conodonts in November 1952, the number of papers dealing with this group increased from a low of 13 (in 1952) to an unprecedented high of 84 in 1959.

Hiltermann's bibliography is of a new type in two respects. It arranges the information according to periods, and it is annotated. The first is of advantage for the stratigrapher, who may confine himself to the period concerning his work (and for that matter single issues are available). The latter seems to me highly valuable for the short annotations. Those are similar in fashion to Hiltermann's annual bibliographies of micropaleontology in Germany published in Micropaleontology. They give quick evidence of papers which contain new species or important taxonomic data.

The scope of this work is not to give a complete review of the entire literature on micropaleontology, but is to give a selection with emphasis on stratigraphy. The somewhat uneven coverage for different periods partly reflects the present status of research interests. Additions of literature from Russia and of chapters to the Paleozoic-Triassic would be useful.

This book will be highly valuable for quick basic references, particularly to those who do not have access to a large library. Besides, it is considered that everybody leafing through it will pick up some valuable information or references which will be fruitful for his particular work.

KLAUS J. MÜLLER
Technische Universität Berlin

JOURNAL OF PALEONTOLOGY, V. 35, NO. 6, P. 1246, NOVEMBER, 1961

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